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AD-601 179

RIGID FOAM PLASTICS SHELTERS -- STRUCTURAL TESTS OF REINFORCED FIBERGLASS PLASTICS BEAMS, HONEY-COMB FLOOR PLANELS, AND EXPERIMENTAL GREENLAND BUILDING

May 1964

U. S. Army Engineer Research and Development Laboratories

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Technical Report 1775-TR

RIGID FOAM PLASTICS SHELTERS-- STRUCTURAL TESTS OF REINFORCED FIBERGLASS PLASTICS BEAMS, HONEYCOMB FLOOR PANELS, AND EXPERIMENTAL GREENLAND BUILDING

1 May 1964

U. S. Army Engineer Research And Development Laboratories

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Technical Report 1775-TR

RIGID FOAM PLASTICS SHELTERS--STRUCTURAL TESTS OF REINFORCED FIBERGLASS PLASTICS BEAMS, HONEYCOMB FLOOR PANELS, AND EXPERIMENTAL GREENLAND BUILDING

Task 1D643303D550-04
(Formerly 8F71-04-001-04)

1 May 1964

Distributed by

The Commanding Officer
U. S. Army Engineer Research and Development Laboratories

Prepared by

Robert K. Hedrick and Abraham Perez
Developmental Fabrication Branch
Technical Service Department

PREFACE

The work covered by this report was conducted under the authority of Task 8F71-04-001-04 (now Task 1D643303D550-04). A copy of the task card is included as Appendix A.

The period covered is 27 April 1961 through 30 March 1962.

CONTENTS

SUMMARY

This report covers structural tests conducted at the U. S. Army Engineer Research and Development Laboratories to evaluate rigid foam plastics shelters.

Based on the test results, it is concluded that:

a. It is feasible to fabricate structural members by using fiberglass-polyester skins over either polyurethane core or paper honeycomb core.

b. Bonding between the skins and the core material is of utmost importance in stressed-skin design.

RIGID FOAM PLASTICS SHELTERS--STRUCTURAL TESTS OF REINFORCED FIBERGLASS PLASTICS BEAMS, HONEYCOMB FLOOR PANELS, AND EXPERIMENTAL GREENLAND BUILDING

I. INTRODUCTION

1. Subject. This report covers structural tests conducted at the U. S. Army Engineer Research and Development Laboratories (USAERDL) to evaluate rigid foam plastics shelters.

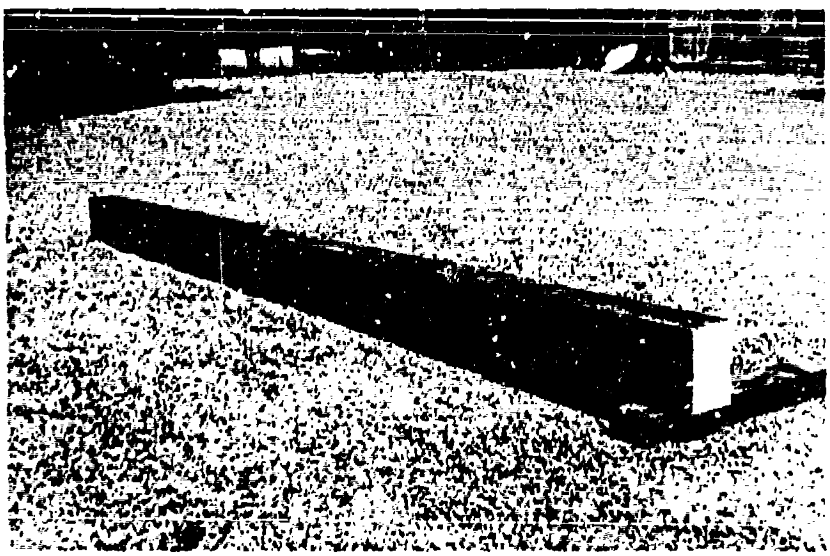
2. Background. Military prefabricated buildings are normally produced in a fabricating plant and shipped to worldwide locations for erection and use. The logistic problems of transporting heavy tonnage and large volume of bulky building panels lent emphasis to investigation of rigid foam plastics as a building material. The foam plastics materials offer a solution to the problems by providing a worldwide-use building that is considerably lighter in weight and is fabricated of material expanded approximately 30 times its original volume on the site, thus reducing shipping volume manyfold. The state-of-the-art in foaming plastics has shown the concept of shipping drums of liquid resin and fabricating plastics buildings in remote areas to be feasible.

Paper honeycomb is being investigated in conjunction with the rigid foam plastics buildings project as a means of adding reinforcement, where needed, to the foam plastics material. When used as stressed-skin panel core material, paper honeycomb offers approximately the same logistic advantage as foam plastics. The paper honeycomb is procurable in prefabricated folded slices which expand 20 to 30 times the shipping volume. A high-strength, durable building panel is produced when fiberglass skins are bonded to the surfaces of the expanded paper. The economy and strength-weight ratio attributes are as high as or higher than those of any other known panel core material; therefore, paper honeycomb is very desirable for field fabrication.

II. INVESTIGATION

3. Reinforced Fiberglass Plastics Beams. Three reinforced fiberglass plastics beams were fabricated with polyurethane foam plastics core material and tested as stringer supports for foam plastics floor

sections. The beams were designed for supporting a uniform floor load of 60 pounds per square foot when spaced on 3-foot centers with a span of approximately 12 feet. Beams 1 and 2 were cast in a 16-foot-long mold; the core for Beam 3 was cast by slip mold technique and was 7 feet 2-3/4 inches long. A short mold which moved vertically on a fixed rail was used for the slip mold technique of fabrication. The mold was approximately 2 feet long and was open at the top and bottom. Resin components poured in the top of the mold expanded, set, and extruded as a beam from the bottom of the mold. Four rolls of paper, fixed at the top of the mold with the free end of the paper passing through the mold and secured at the rail base platform, supplied the mold lining necessary to prevent adherence of the foam to the moving mold. Beam 1 was fabricated by casting the polyurethane core, removing the core from the mold, then spraying the fiberglass skin. Beam 2 (Fig. 1) was fabricated by spraying the fiberglass skin on the inner surfaces of the mold, then assembling the mold and pouring the polyurethane core to complete the beam. A fiberglass skin was also sprayed over the core of Beam 3.

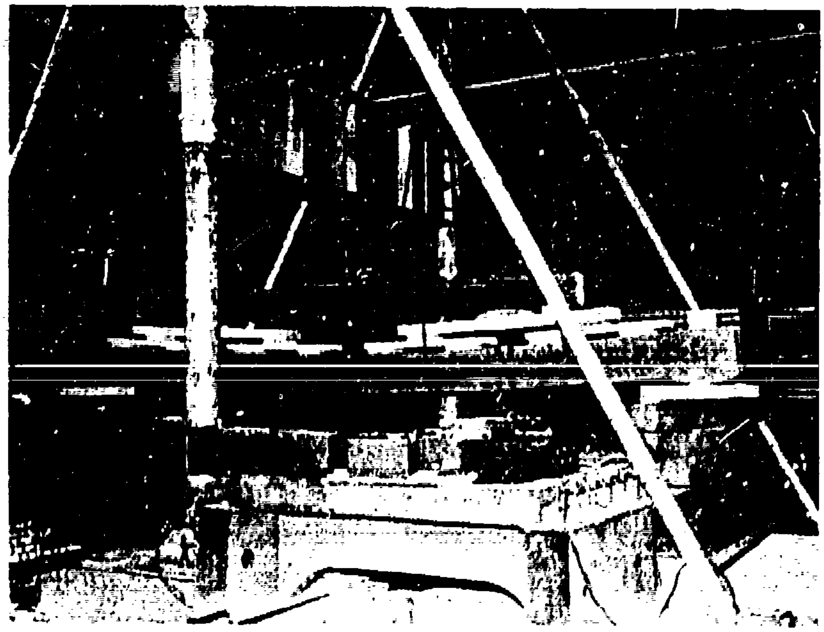


H5177

Fig. 1. Reinforced fiberglass plastics Beam 2.

The effective section modulus of each beam was computed and is shown in Appendix B, Exhibit 1.

Exhibits 2, 3, and 4 of Appendix B show the test setup and location of strain gages for each beam. Beam 2 supported twice as much load as Beam 1 and did not fail until a total load equivalent to a uniform floor load of 118.37 pounds per square foot was applied (Fig. 2). This was to be expected, however, since the section modulus of Beam 2 was much greater than that of Beam 1 (Appendix B, Exhibit 1). Exhibits 5, 6, and 7 of Appendix B show the applied loads, resulting moments, and corresponding measured stresses for each beam.



H5219

Fig. 2. Test setup for applying uniform load to reinforced plastics beams (Beam 2).

Results of the tests for the three beams are summarized in Table I.

After failure of the beams (Figs. 3 and 4), four composite specimens were cut from each beam (Figs. 5 and 6) and subjected to additional laboratory testing to determine the physical properties of each specimen. Results of these tests are presented in Appendix C.

Table I. Strain Gage Tests of Reinforced Fiberglass Plastics Beams

Property	Beam No.		
	1	2	3
Test Span (ft, in.)	14, 9-3/4	14, 9-3/4	6, 0
Failure Load (kips)	2.50	5.25	4.00
Floor Load (psf)[a]	56.26	118.37	(b)
Failure Moment (ft-kips)	5.40	10.50	3.09
Maximum Measured Stress (ksi)[d]	4.20	-5.00[c]	3.18
Maximum Average Stress (ksi)	3.67	-4.73[c]	2.94
Corresponding Applied Moment (ft-kips)	4.47	10.00	2.71
Deflection (in.)	2.38	3.62	1.00
Type of Failure	Moment	Moment	Bearing
Weight of Beam (lb)	72.5	77.8	30.0

(a) Three-foot center-to-center spacing.
(b) Reduced span.
(c) Compressive stress.
(d) ksi - kips per square inch.

4. Honeycomb Floor Panels. Several different floor concepts were considered, and honeycomb floor panels were selected because they offer one of the more feasible means of providing a floor of sufficient strength for the 16-foot-wide building.

The floor growth (arching effect) in the Greenland snow tunnels, amounting to approximately 2 inches per year, presented a problem in the design of the floor. Experience has revealed that the best method of dealing with the annual rise in the tunnel floor is to provide lateral floor panels with a simple beam span. Supporting stringers run longitudinally with the

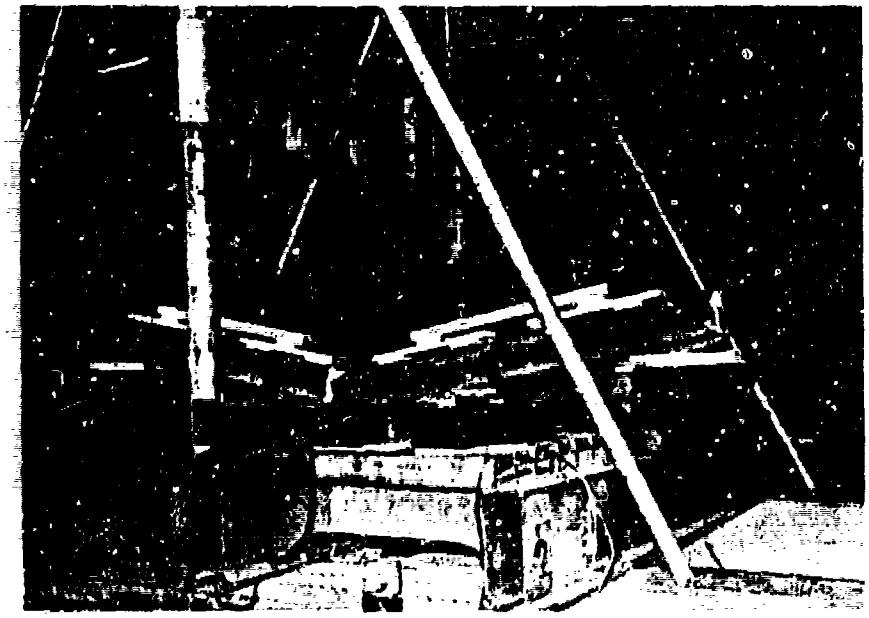


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Fig. 3. Test failure of reinforced fiberglass plastics Beam 1.

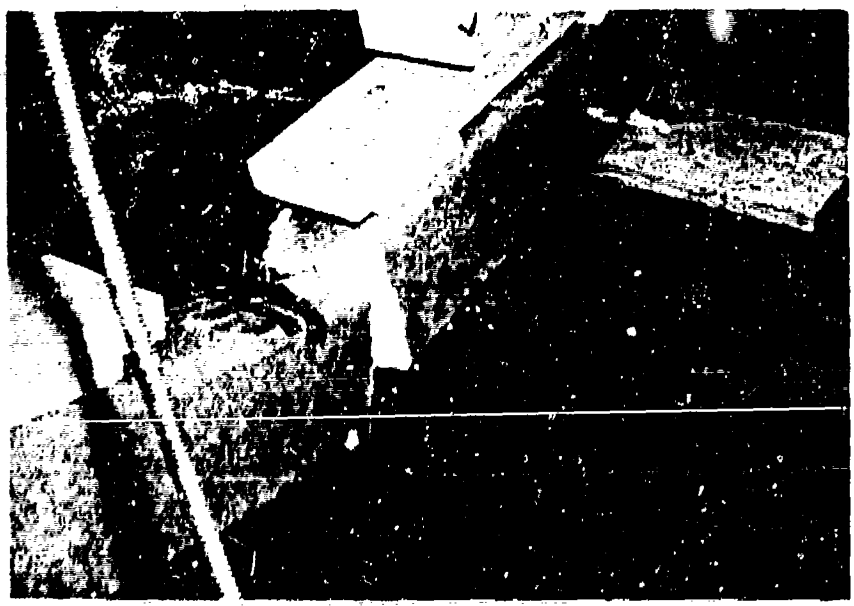

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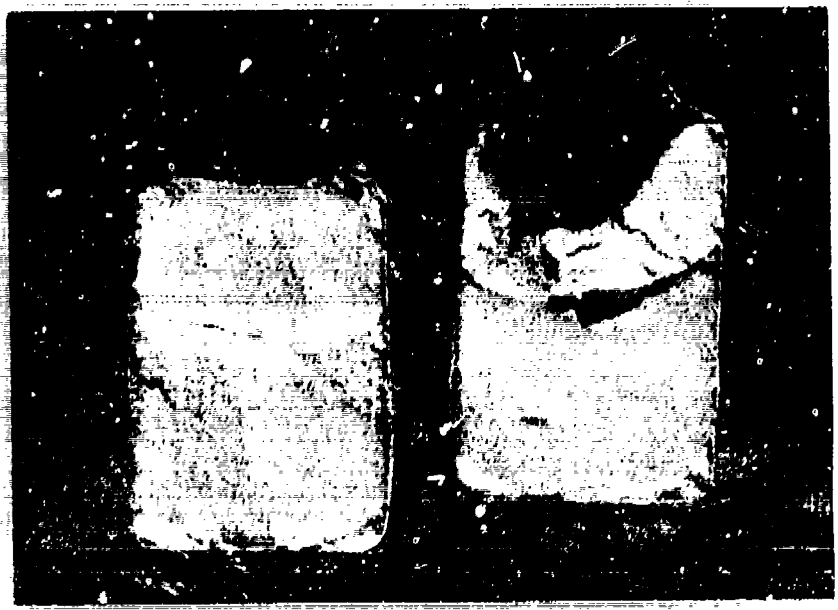
Fig. 4. Close-up of test failure (Beam 1).



H5183

Fig. 5. End view of test failure (Beam 1).

H5221

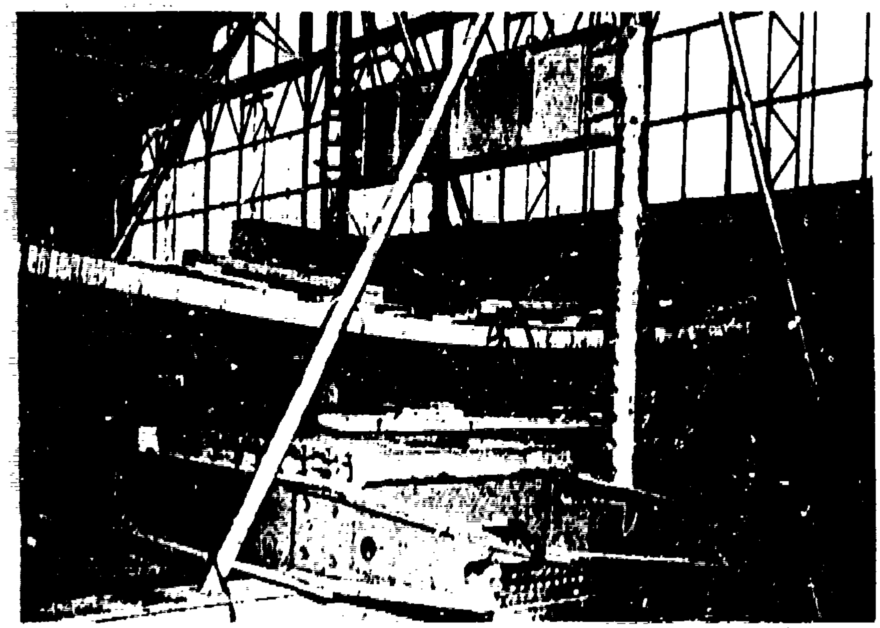
Fig. 6. End view of test failure (Beam 2).

building, near the outside walls. With this type of footing, the floor can be supported a sufficient distance off the tunnel floor to allow for several years of tunnel floor growth before it becomes necessary to raise the building. Also, the building can be more easily raised and shimmed in increments, when necessary.

The paper honeycomb core material was procured and shipped to the field in the unexpanded form. The honeycomb core was an untreated paper (99 pounds per ream) with 3/4-inch cells. The field expansion ratio over the shipping volume was over 20 to 1, which provided a logistic advantage similar to that of polyurethane foam. Fabrication of a honeycomb panel consisted of saturating woven fiberglass cloth with epoxy resin, expanding the honeycomb core material, and placing the saturated fiberglass sheets on the core material. The final operation consisted of placing "sandwich" panel in a vacuum bag and allowing the panel to cure under vacuum (5 to 10 inches of mercury) to insure a good bond between the paper honeycomb core and the fiberglass skins. The field fabrication setup for a 3- by 16-foot honeycomb panel was made by two men in approximately 1 hour.

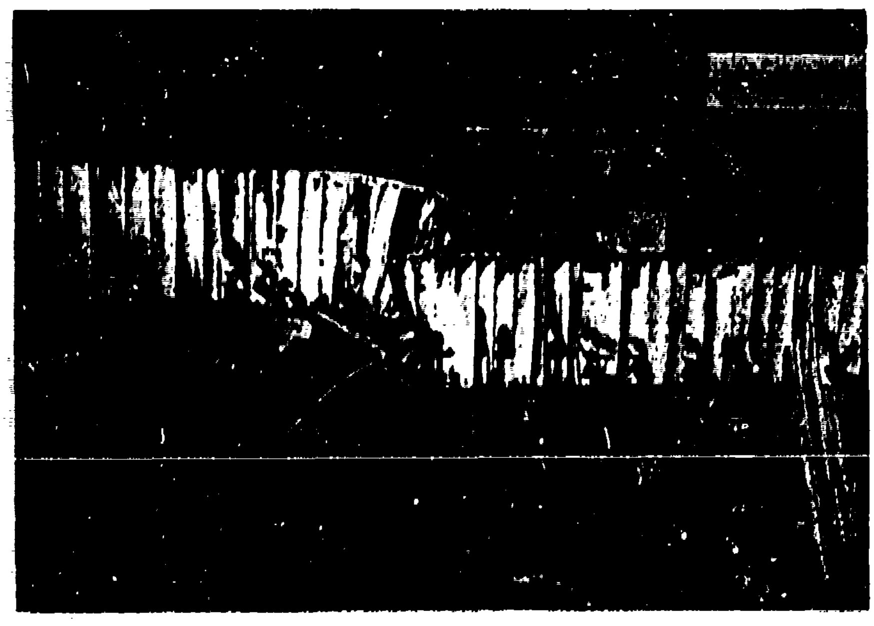
Tests were conducted on 4-, 5-, and 6-inch-thick panels to determine the most suitable panel and span to support a design live load of 50 pounds per square foot without exceeding a deflection ratio of 1/240 of the unsupported span. To shorten the span, it was determined that the building could cantilever approximately 1 foot over each outside stringer without any detrimental effects, since the buildings would not be subjected to any snow or wind load forces in the Greenland snow tunnels. Thus, the clear floor span was reduced to 12 feet by using two 1-foot-wide stringer supports. The effective section modulus of each size panel was computed as shown in Appendix B, Exhibit 8.

One 4-inch-thick, one 5-inch-thick, and three 6-inch-thick honeycomb panels were strain gaged and tested to failure. Expanded polystyrene beads were added to one of the 6-inch-thick panels in an effort to arrive at an expedient field method of adding insulation and improving the thermal conductivity quality of the panels. Exhibits 9 through 13 of Appendix B show the test setup and location of strain gages for each panel. Exhibits 14 through 18 show the applied loads, resulting moments, and corresponding measured stresses. Panel 4 was tested on a 16-foot simple beam span and supported a greater load than any of the panels tested. Failure did not occur until a total load equivalent to a uniform floor load of 122 pounds per square foot was applied (Figs. 7 and 8). Results of the strain gage tests for the five panels are summarized in Table II.



J4005

Fig. 7. Test of honeycomb floor Panel 4.



J4009

Fig. 8. Close-up of shear failure (Panel 4).

Table II. Strain Gage Tests of Honeycomb Floor Panels

Property	Panel No.				
	1 (4-in.)	2 (5-in.)	3 (6-in.)	4 (6-in.)	5 (6-in.)
Failure Load, DL + LL (kips)	2.93	2.93	2.93	5.87	1.87
Equivalent Floor Load (psf)	69.50	81.30	97.70	122.30	39.00
Failure Moment (ft-kips)	5.28	4.52	3.76	12.40	3.96
Live Load Stresses:					
Max Measured Stress (ksi)	4.10	-2.85	-1.95	8.09	-1.32
Max Average Stress (ksi)	3.89	-2.77	-1.90	7.01	-1.24
Corresponding Live Load Moment (ft-kips)	4.38	3.00	2.50	10.50	2.00
Type of Failure	Moment	Moment	Moment	Shear	Moment
Weight of Panel (lb)	88	85	80	126	161

NOTE: DL - dead load.
LL - live load.
ksi - kips per square inch.

Specimens were cut from honeycomb Panel 3 and analyzed by the USAERDL Materials Branch to determine physical properties of the woven fiberglass skin material. Results of these tests are presented in Appendix D.

5. <u>Experimental Greenland Building</u>. Structural tests were performed on the building to determine the wind and snow load capacity, the

location of critical stresses, and the maximum deflection under loaded conditions. To simulate the most severe condition of loading, the building was tested without benefit of end walls. Figures 9 and 10 show the test setup for application of simulated wind and snow loads, respectively. The design wind pressures and resulting wind loads for a 9-foot test module were computed and are shown in tabular form in Exhibits 19 and 20 of Appendix B. Wind load forces were computed in accordance with Metal Building Manufacturers Association Standards which are equally applicable to all types of construction.

Simulated wind loads were applied by means of ratchet chain hoists, and simulated snow loads were applied by means of sandbags placed on the roof. Electrical strain gages were placed as shown in Exhibits 21 and 22 of Appendix B to determine the stresses under each increment of loading. A maximum simulated wind load equivalent to a 100-mile-per-hour wind was being applied when failure occurred. The test module did not collapse; however, the skin ruptured to the extent that additional load could not be sustained. Exhibit 23 of Appendix B shows the tabulated stresses and deflections produced by the simulated wind load test. A new 12-foot shelter test module was erected for the snow load tests, and roof loads were applied in increments until a maximum short-term roof load of 50 pounds per square foot was applied without failure occurring. Exhibit 24 of Appendix B shows each increment of loading and a tabulation of the resulting stresses. After the strain data were obtained, the test module was allowed to remain under 20-pound-per-square-foot simulated snow load for 72 hours and under 20- and 40-pound-per-square-foot loads for 24 hours to determine the amount of creep or set occurring under sustained load conditions. Appreciable set was not measured until the 40-pound-per-square-foot load was removed, and failure did not occur until the shelter retained a 50-pound-per-square-foot load for 4 hours (Fig. 11). Exhibit 25 of Appendix B shows the deflection and set resulting from the sustained conditions of loading.

III. DISCUSSION

6. Reinforced Fiberglass Plastics Beams. When the plastics beams were designed, the foam core was considered as being noneffective in contributing to the load-carrying capacity. However, a comparative analysis of measured stresses versus theoretical stresses revealed that the theoretical stresses were considerably higher. This discrepancy could be

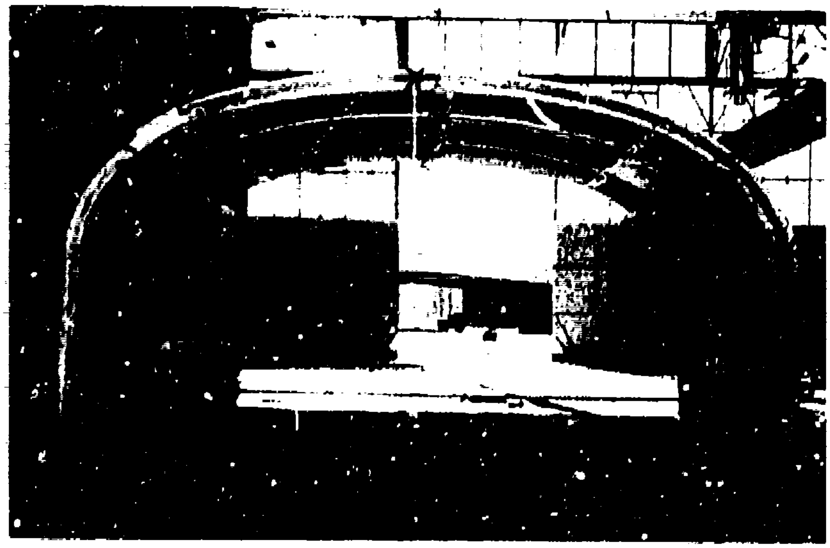


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Fig. 9. Test setup for application of simulated wind forces on shelter test module.

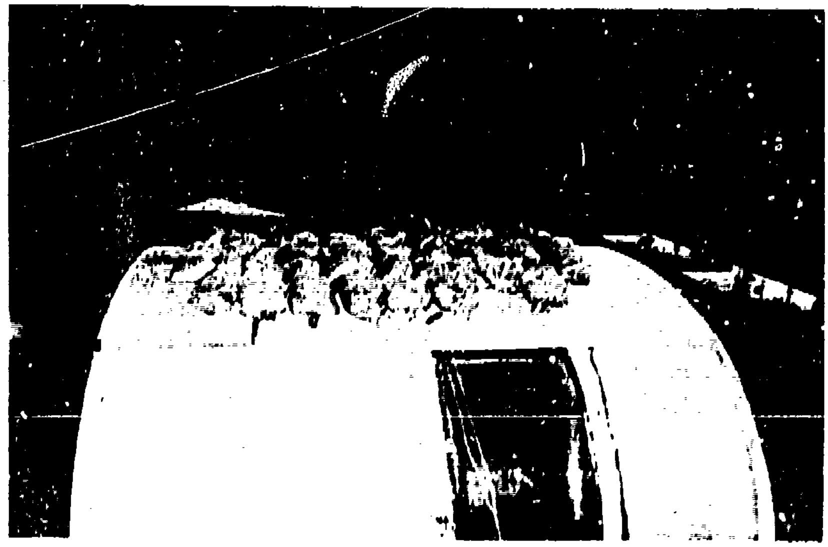

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Fig. 10. Test setup for application of simulated snow load on shelter test module.

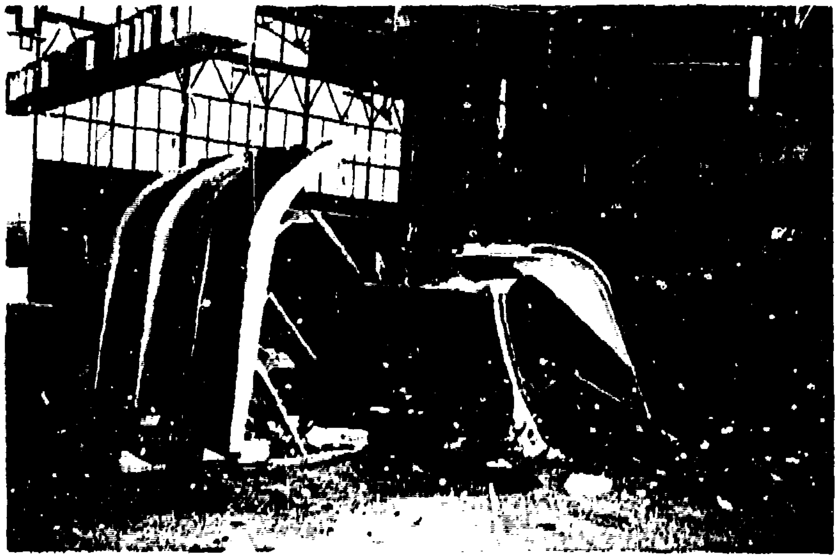

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Fig. 11. Failure of shelter test module under 50-pound-per-square-foot sustained simulated snow load.

partially due to variations in thickness of the laminates as reported in Appendix C (Materials Branch Report 9289-1); however, it is more likely that the foam core section is slightly effective (from 5 to 10 percent) in producing a composite beam effect which contributes to the flexural load-supporting capacity of the beam. Additional testing is planned, using homogeneous premolded fiberglass sheets as panel skins to study the composite beam theory with a foam plastics core material.

7. Honeycomb Floor Panels. Although the strength of the 6-inch-thick, 16-foot-long honeycomb panel was found to be more than 2½ times the strength required to support the 50-pound-per-square-foot design floor load, the deflection of the panel is so great that it cannot be considered as a simple beam floor member unless each end of the panel is cantilevered approximately 2 feet over the floor-supporting stringers. This arrangement permits negative moment for 2.35 feet on each end of the panel and reduces the critical positive moment deflection producing length from 16 feet to 11.30 feet. At 50-pound-per-square-foot floor load, the total deflection in 6-inch-thick Panel 4 was interpolated to be 2.59 inches when the panel was

supported on a 16-foot span. The maximum allowable deflection for floors in prefabricated military buildings has been established at 1/240 of the span (0.80 inch) for a 16-foot-wide building. A rerun of the test of the 6-inch-thick, 16-foot-long panel with a clear span of 12 feet and a uniform load of 50 pounds per square foot produced a maximum deflection of 0.83 inch, which is considered acceptable.

Test of 6-inch-thick Panel 5 revealed that a loss in structural capacity occurred when the honeycomb core of the panel was partially filled with polystyrene beads. Intermingling of the beads between the epoxy resin skin and the paper honeycomb core prevented a good bond of the fiberglass skins to the core material. The top and bottom skins were bonded in one operation, and it is believed that the problem could be alleviated by bonding the skins in two operations. Thus, the bottom skin would be bonded to the honeycomb core and allowed to cure, the beads would be added, then the top skin would be bonded to the core. Calculations show that a 6-inch-thick honeycomb panel with 2 inches of polystyrene beads and a 2-inch-thick polyurethane panel with fiberglass skins have approximately the same U factor. One of the most serious deficiencies in the use of polystyrene beads on the site is the short shelf life of the beads in the unexpanded state. This shelf life under optimum conditions has been determined to be approximately 1 year. Other types of insulation material that have a longer shelf life and can be expanded on the site are being investigated in an effort to improve the thermal conductivity of honeycomb material.

The paper honeycomb material used for these tests and for the Camp Century, Greenland, building was of the untreated type which was suitable for the Greenland snow tunnels where no moisture problems exist. For an all environmental building, however, it will be necessary to provide a core material that is resistant to moisture, fungi, bacteria, rodents, and so forth; and it is desirable that this be accomplished without the field heat-curing process required for phenolic-impregnated paper honeycomb. Therefore, investigations are being carried out with pretreated paper honeycomb and other honeycomb materials that can be expanded on the site and require no field heat-cure processing.

8. Experimental Greenland Building. The structural test results show that the most critical stresses on the shelter occur at the ridge under both wind (Gages 15 and 16) and snow load (Gages 13 and 14) conditions; however, the highest stresses (3.9 and 3.8 kips per square inch) were recorded under the 50-pound-per-square-foot simulated snow load test. The

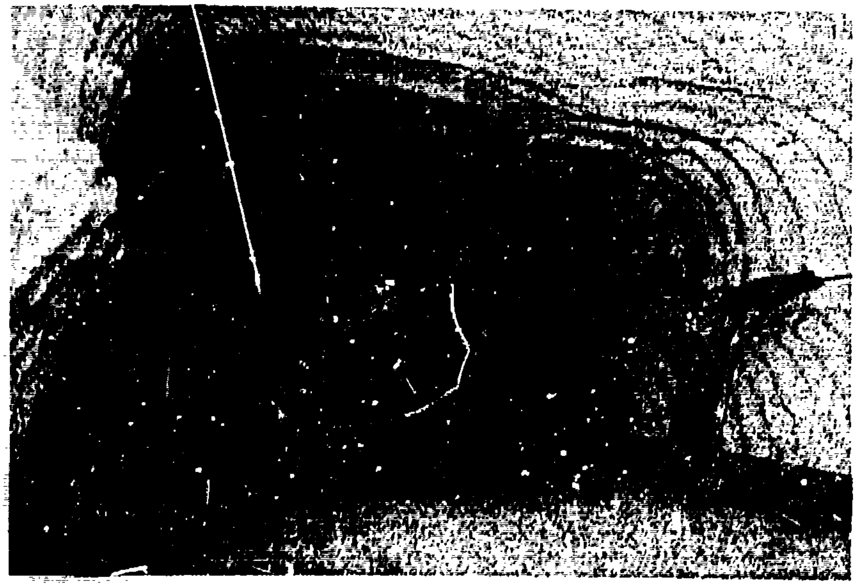

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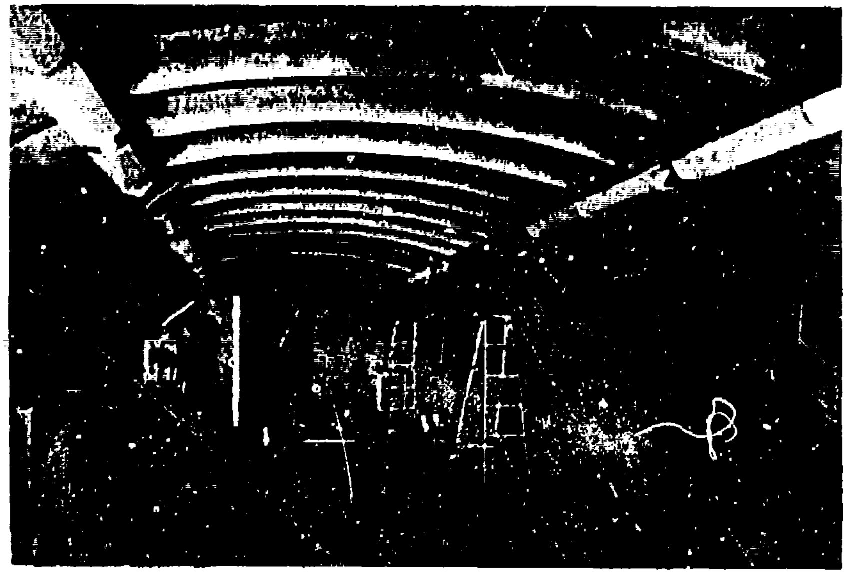
Fig. 12. Polyurethane plastics building in the ice tunnel at Camp Tuto, Greenland.

H10887
Fig. 13. Polyurethane plastics building in a snow tunnel at Camp Century, Greenland.



H10889

Fig. 14. Interior of polyurethane plastics building at Camp Century, Greenland.

tests show that the thickness of the panel ribs should be increased approximately 1 inch in the ridge area. This would effect a more satisfactory distribution of stress and produce a shelter which could in all probability be rated for 40-pound-per-square-foot snow loads or 80-mile-per-hour winds with gusts up to 120 miles per hour (with proper tiedown arrangements) when erected with end walls such as the two buildings used for troop occupation tests in Greenland (Figs. 12 through 14).

IV. CONCLUSIONS

9. Conclusions. Based on the test results, it is concluded that:

a. It is feasible to fabricate structural members by using fiberglass-polyester skins over either polyurethane core or paper honeycomb core.

b. Bonding between the skins and the core material is of utmost importance in stressed-skin design.

APPENDICES

APPENDIX A

AUTHORITY

RDT & E PROJECT CARD

1. TYPE OF REPORT: [X] NEW [ ] FINAL [ ] REPLACES (No. & Date)

REPORT CONTROL SYMBOL: CSCRD-1 (R2)

2. PROJECT TITLE (Task): Rigid Foam Plastic Shelters

3. SECURITY OF PROJECT: U

4. PROJECT NO.: 8F71-04-001

5. TASK: 8F71-04-001-04

6. REPORT DATE: 5 January 1961

7. BASIC FIELD OR SUBJECT: Structures

8. SUB FIELD OR SUBJECT SUB GROUP: Buildings & Utilities

9. CATEGORY: 50

10a. COGNIZANT AGENCY: Corps of Engineers

b. DIRECTING AGENCY: Mil Eng Div, R&D, OCE

c. REQUESTING AGENCY: Office, Chief of Engineers

11a. CONTRACTOR AND/OR GOVERNMENT LABORATORY: USA Engr. Res. & Dev. Labs. Fort Belvoir, Va.

b. CONTRACT NUMBER: None

12. PARTICIPATION BY OTHER MILITARY DEPTS. AND OTHER GOVT. AGENCIES: None

14. SUPPORTING PROJECTS: None

18. EST. COMPLETION DATES:

DEV.	1964
ENGR TEST	1965
USER TEST	1965
OPERATIONAL	1966

13. COORDINATION ACTIONS W/OTHER MILITARY DEPTS. & OTHER GOVT. AGENCIES: None

15. DATE APPROVED:

16. PRIORITY: 1-B

17. BUDGET CODE: 5600

19. EST. SUPPORT LEVEL:

- [ ] UNDER $50,000
- [X] $50,000 - $100,000
- [ ] $100,000 - $250,000
- [ ] $250,000 - $500,000
- [ ] $500,000 - $1,000,000
- [ ] OVER $1,000,000

20. CDOG Ref. Par. 834, 1610v, 1636d(8)

21. SPECIAL CODES:

22. REQUIREMENT AND/OR JUSTIFICATION

a. Requirements exist for prefabricated lightweight foamed plastic rigid shelters for medical, maintenance, and special climatic operations; for missile support shelters for storage, standby, and radar activities; and for sled mounted wanigans. The concept embraces fabrication of such items in the field from both foamed plastic sections or panels; and by spraying removable air inflated and/or removable frame type forms with the plastic foam material after which the forms can be removed and reused.

b. The above concept is in consonance with paragraph 1610v, CDOG, which requires a reduction in the drain on the national economy, and makes mandatory the use of prefabricated and knockdown shelters such as those envisioned. Missile support items are covered by CDOG, paragraph 834, and wanigans by paragraph 1636d(8).

23. Brief of Project and Objective

a. Brief:

(1) Objective: Development of lightweight rigid foam plastic resins and portable field spraying equipment, including techniques of foaming in place (or on the side) shelters and buildings, utilizing panel, module and mold construction methods.

(2) Technical Characteristics: See Exhibit A.

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RDT & E PROJECT CARD CONTINUATION	REPORT DATE 6 January 1961	PROJECT NO. TASK 8F71-04-001-04

b. Approach:

(1) Engineer Research and development work will be performed by the technical staff of the Corps of Engineers with assistance from research and engineering staffs of commercial suppliers as needed.

(2) Engineering research and studies will be undertaken in the following areas to determine the most suitable means of satisfying the overall military requirements:

(a) Development of economical, lightweight, rigid foam plastic resins, including reinforced rigid foam plastics which can be foamed and stored in all environments.

(b) Portable field spraying equipment.

(c) Techniques of foaming shelters and buildings in all environmental conditions.

(d) Methods of internally reinforcing rigid plastic foam for use in shelters and buildings where high snow and wind loads are encountered.

(e) Development of structural design criteria for rigid foam plastics including reinforced rigid foam plastics.

(3) Comprehensive engineering tests of pilot model shelter molding and spraying equipment, including techniques, will be conducted to determine the general suitability and to determine necessary modifications prior to submittal for user tests. Drawing and purchase descriptions shall be modified to reflect the equipment passing the tests.

(4) Service test equipment shall then be procured and furnished to the weapons systems or application for which the equipment was developed.

(5) After all tests and necessary revisions of the equipment have been accomplished, complete drawings and specifications will be prepared and forwarded to the Chief of Engineers, together with recommendations regarding classification action on the equipment developed.

c. Tasks: Not applicable

d. Other Information:

(1) Scientific Research: None

(2) References: None

(3) Discussion:

Agencies interested in this project in addition to the Corps of Engineers, with which liaison will be maintained and which will be furnished copies of reports on the project are USCONARC, Medical Corps, Quartermaster Corps,

EXHIBIT "A"

TECHNICAL CHARACTERISTICS FOR
RIGID FOAM PLASTIC SHELTERS

1. The rigid type shelters formed in the field by use of low density core materials shall consist of all weather units in all ranges of covered space provisions, including maintenance of vehicles, missile, and other mechanical/electrical equipment, command posts, air stations, fire direction centers, personnel housing, collective protection and other general purpose requirements.

2. Means shall be developed for fabrication of shelters under all environmental conditions as specified in AR 705-15.

3. Shelters shall be capable of being constructed for all climate operations to withstand steady winds of 60 miles per hour and to support snow loads of 20 pounds per square foot. Features shall be incorporated (in kit form if applicable) to permit the shelters to be used in areas where snow loads reach 40 pounds per square foot and wind loads correspond to velocities of 80 miles per hour with gusts of 120 miles per hour.

4. The shelters shall be made of the smallest possible number of components and component types, and be capable of easy handling and rapid erection by personnel within companies and battalions.

5. The shelters shall be compatible with chemical, biological, and radiological protection.

6. The shelters shall be durable, weatherproof and fire retardant. They shall not be subject to appreciable weather deterioration, or attack by insects, fungi, bacteria, or rodents.

7. Wearing surfaces, both exterior and interior, shall withstand normal barracks type use.

8. The completed system shall permit erection of variable length shelters.

9. Provisions shall be made in the design of the shelters for the installation of standard or fabricated on the site doors and windows located on both sides and/or ends.

10. The shelter equipment shall be lightweight and portable for field service, sufficiently rugged to withstand prolonged cross-country movement and transportation in Phase II of airborne operations. It shall be designed with maximum simplicity commensurate with intended performance and be capable of manufacture in quantity by modern fabrication methods.

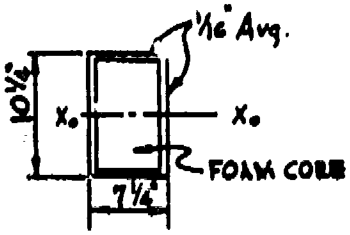
APPENDIX B

DATA SHEETS **Exhibit 1**

CALCULATION OF SECTION MODULI

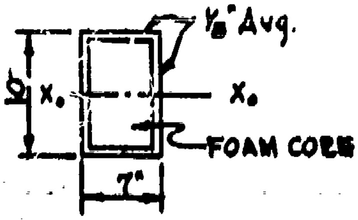
BEAM #1

$$I_o = I_1 - I_2$$
$$= \frac{7.25 \times 10.25^3}{12} - \frac{7.125 \times 10.125^3}{12}$$
$$= 650.62 - 616.30$$
$$= 34.32 \text{ in.}^4$$
$$S = \frac{I}{c} = \frac{34.32}{5.125} = 6.70 \text{ in}^3$$



BEAM #2

$$I_o = I_1 - I_2$$
$$= \frac{7 \times 10^3}{12} - \frac{6.75 \times 9.75^3}{12}$$
$$= 583.33 - 521.36$$
$$= 61.97 \text{ in.}^4$$
$$S = \frac{I}{c} = \frac{61.97}{5} = 12.39 \text{ in.}^3$$



BEAM #3

$$I_o = I_1 - I_2$$
$$= \frac{7 \times 10^3}{12} - \frac{6.75 \times 9.5^3}{12}$$
$$= 583.33 - 482.27$$
$$= 101.06 \text{ in.}^4$$
$$S = \frac{I}{c} = \frac{101.06}{5} = 20.21 \text{ in}^3$$

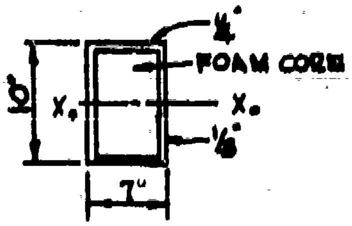
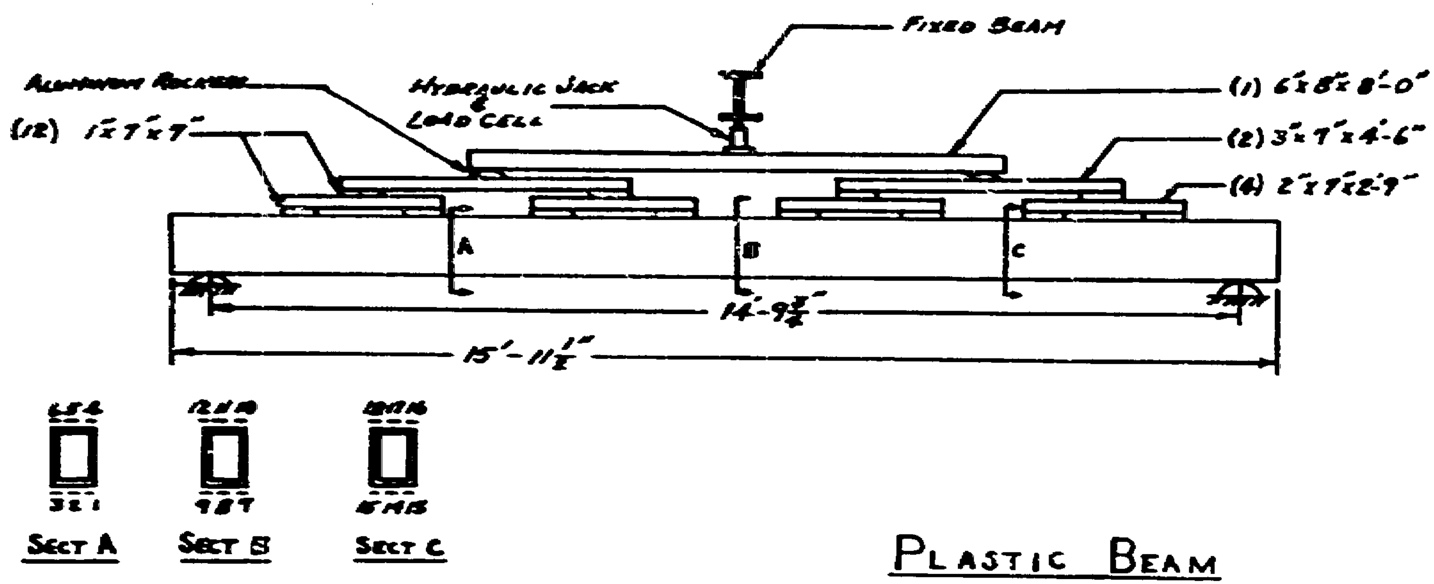


Exhibit 2

Loading Diagram Plastic Beam No. 1



Strain Gages (Location)
[1 1/2" x 10 1/4" Ave. x-sect]

Note (1) Ave Thickness of Fiberglass 1/16"

(2) All Loading Members are Wood. AL WT = 345#

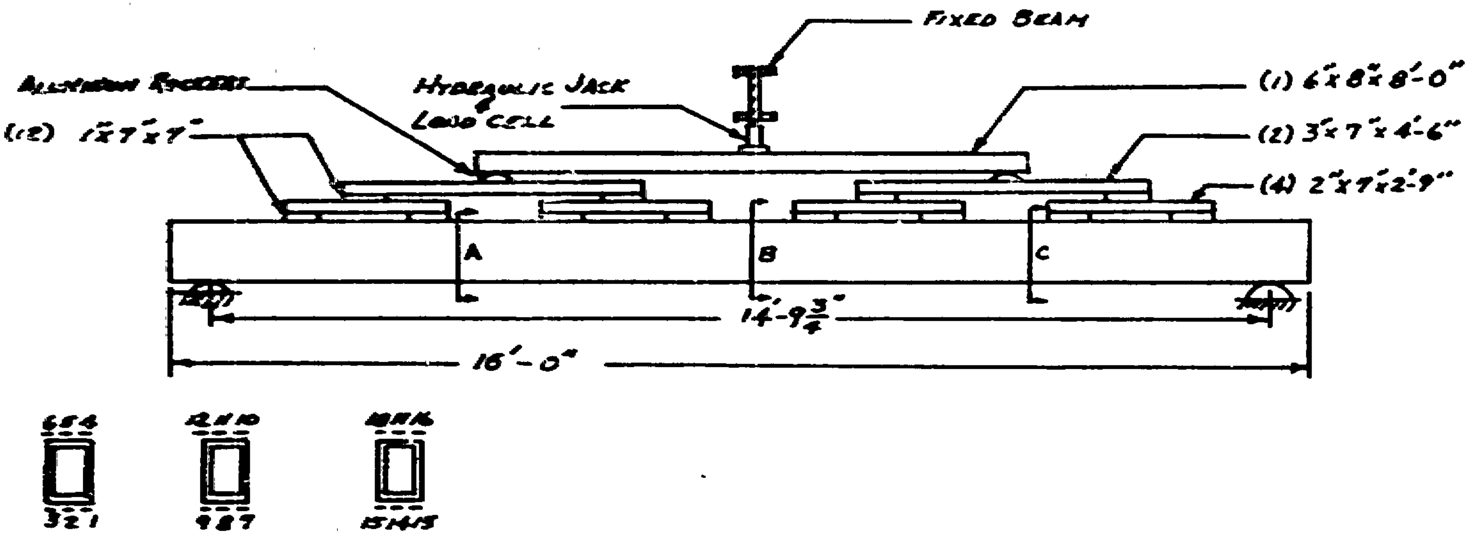
Plastic Beam

Polyurethane Core-Fiberglass Skin

WT= 72.5#

Exhibit 5

LOADING DIAGRAM PLASTIC BEAM No. 2



SECT A SECT B SECT C

STRAIN GAGES (LOCATION)
[7" x 10" Ave. x-sect]

NOTE (1) Ave Thickness of Fiberglass 1/8"

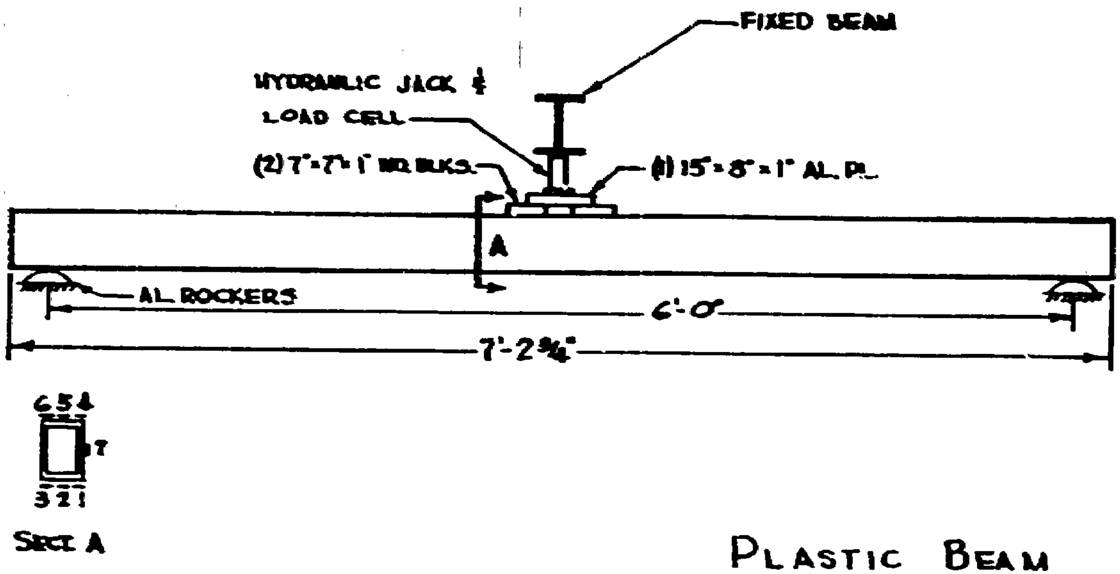
(2) All Loading Members are wood. Al. Wt= 34#

PLASTIC BEAM

POLYURETHANE CORE - FIBERGLASS SKIN

WT = 77.8#

LOADING DIAGRAM PLASTIC BEAM No. 3



STRAIN GAGES (LOCATION)
[7"×10" AVE. X-SECT.]

(1) AVE. THICKNESS OF FIBERGLASS SKIN:
(a) FLANGE: 1/16"
(b) WEB: 1/8"
(2) LOADING MEMBERS D.L. WT.: 85#

PLASTIC BEAM
POLYURETHANE CORE - FIBERGLASS SKIN
WT = 30.0#

Exhibit 5

E= 0.75×10⁶ PSI.

PLASTIC BEAM NO. 1
MOMENT TEST, TABLE OF STRESSES (KSI)

Moment (DL+LL) FT-K - ℄		1.70	1.93	2.62	3.53	4.47	5.40		
Line Load Kips/Girder		0.50	0.625	1.00	1.50	2.00	2.50		
GAGES	1	0.420	0.517	0.810	1.395	1.550	FAILURE NO READINGS		
	2	0.315	0.405	0.636	1.090	1.230			
	3	0.353	0.450	0.690	1.185	1.260			
	4	-0.360	-0.435	-0.698	-1.210	-1.340			
	5	-0.420	-0.510	-0.818	-1.425	-1.580			
	6	-0.457	-0.555	-0.885	-1.550	-1.720			
	7	0.742	0.930	1.455	2.630	3.020			
	8	0.960	1.190	1.852	3.310	3.780			
	9	1.035	1.300	2.020	3.680	4.200			
	10	-0.660	-0.825	-1.390	-2.330	-2.600			
	11	-0.607	-0.705	-1.290	-2.140	-2.380			
	12	-0.562	-0.698	-1.150	-2.050	-2.260			
	13	0.475	0.848	1.300	2.300	2.600			
	14	0.548	0.697	1.062	1.880	2.120			
	15	0.615	0.773	1.730	2.070	2.340			
	16	-0.368	-0.457	-0.720	-1.250	-1.370			
	17	-0.375	-0.472	-0.734	-1.240	-1.350			
	18	-0.360	-0.442	-0.690	-1.190	-1.310			
℄ Deflection (ins.)	D.L.								
	L.L.	0.769(1)	0.778	1.229(2)	2.163	2.381	FAILURE		

(1) Date: 27 April '61.
(2) " : 28 " '61.

PLASTIC BEAM NO. 2
MOMENT TEST, TABLE OF STRESSES (KSI)

E = 0.85×10⁶ PSI.

Moment (DL+LL) FT-K - ℄		1.70	2.63	3.56	4.48	4.96	5.42	6.32	6.79
Live Load - Kips/Girder		0.50	1.00	1.50	2.00	2.250	2.50	3.00	3.250
GAGES	1	0.325	0.714	1.150	1.548	1.740	1.900	2.320	2.400
	2	0.298	0.629	1.010	1.360	1.520	1.660	2.000	2.060
	3	0.382	0.808	1.290	1.740	1.950	2.130	2.580	2.670
	4	-0.332	-0.730	-1.210	-1.620	-1.840	-2.020	-2.460	-2.540
	5	-0.323	-0.714	-1.170	-1.580	-1.780	-1.950	-2.400	-2.440
	6	-0.357	-0.790	-1.280	-1.720	-1.940	-2.100	-2.540	-2.620
	7	0.366	0.815	1.325	1.790	2.050	2.210	2.730	2.780
	8	0.325	0.705	1.140	1.520	1.730	1.870	2.290	2.320
	9	0.400	0.858	1.410	1.910	2.150	2.340	2.880	2.940
	10	-0.391	-0.867	-1.430	-1.910	-2.160	-2.340	-2.910	-2.950
	11	-0.374	-0.884	-1.490	-1.990	-2.420	-2.530	-3.110	-3.170
	12	-0.382	-0.858	-1.400	-1.900	-2.150	-2.330	-2.900	-2.940
	13	0.357	0.782	1.260	1.720	1.950	2.110	2.570	2.650
	14	0.298	0.645	1.040	1.390	1.580	1.710	2.090	2.160
	15	0.323	0.688	1.100	1.490	1.680	1.840	2.240	2.300
	16	-0.348	-0.740	-1.190	-1.590	-1.790	-1.930	-2.450	-2.400
	17	-0.348	-0.730	-1.180	-1.580	-1.790	-1.920	-2.450	-2.390
	18	-0.306	-0.663	-1.060	-1.430	-1.610	-1.720	-2.120	-2.150
℄ Deflection (ins.)	D.L.								
	L.L.	0.334	0.705	1.138	1.618	1.680	1.813	2.250	2.313

Exhibit 6 (cont'd)

PLASTIC BEAM NO. 2
MOMENT TEST, TABLE OF STRESSES (KSI) (CONT)

E=0.85×10⁶ PSI.

Moment (DL+LL) FT-K – ℄		7.25	7.72	8.20	8.65	9.12	9.55	10.00	10.50
Live Load-Kips/Girder		3.50	3.750	4.00	4.250	4.50	4.750	5.00	5.250
GAGES	1	2.540	2.740	2.980	3.220	3.350	3.640	3.820	
	2	2.190	2.350	2.540	2.460	2.520	2.680	2.780	FAILURE
	3	2.840	3.060	3.320	3.600	3.760	4.100	4.280	
	4	-2.620	-2.930	-3.210	-3.450	-3.590	-4.760	-4.000	
	5	-2.620	-2.860	-3.120	-3.330	-3.480	-3.800	-3.890	
	6	-2.800	-3.020	-3.300	-3.520	-3.680	-3.970	-4.080	NO
	7	3.000	3.200	3.460	3.730	3.900	4.220	4.480	
	8	2.490	2.650	2.840	3.020	3.160	3.410	3.580	READINGS
	9	3.150	3.370	3.630	3.900	4.080	4.400	4.660	
	10	-3.170	-3.390	-3.660	-3.860	-4.060	-4.350	-4.580	
	11	-3.420	-3.650	-3.940	-4.200	-4.420	-4.730	-5.000	
	12	-3.340	-3.400	-3.680	-3.900	-4.080	-4.370	-4.610	
	13	2.830	3.050	3.280	3.540	3.750	4.030	4.270	
	14	2.300	2.460	3.500	2.860	3.010	3.240	3.420	
	15	2.460	2.640	2.820	3.070	3.230	3.490	3.750	
	16	-2.580	-2.750	-2.960	-3.140	-3.300	-3.540	-3.720	
	17	-2.580	-2.750	-2.980	-3.140	-3.300	-3.540	-3.730	
	18	-2.310	-2.460	-2.670	-2.820	-2.950	-3.180	-3.330	
℄ Deflection (ins.)	D.L.								
	L.L.	2.438	2.594	2.781	3.000	3.250	3.438	3.625	

Exhibit 7

E= 0.80x10^6 PSI.

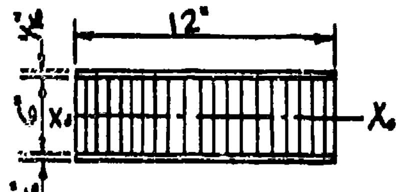
PLASTIC BEAM NO. 3
MOMENT TEST, TABLE OF STRESSES (KSI)

Moment (DL+LL) FT-K - ℄		.461	.836	1.210	1.585	1.960	2.340	2.710	3.090
Live Load-Kips/Girder		0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
GAGES	1	.456	.772	1.192	1.616	2.032	2.504	3.184	
	2	-.372	.732	1.156	1.588	1.948	2.356	2.992	FAILURE NO READINGS
	3	.408	.668	1.044	1.436	1.768	2.124	2.648	—
	4	-.304	-.740	-.972	-1.304	-1.376	-1.560	-1.600	—
	5	-.168	-.532	-.720	-.996	-1.164	-1.216	-.780	—
	6	-.180	-.428	-.580	-.760	-.876	-.872	-.460	—
	7	-.060	-.172	-.212	-.300	-.400	-.568	-.876	—
℄ Deflection (ins.)	DL								
	LL	0.250	0.250	0.250	0.500	0.500	0.500	0.750	1.000

CALCULATION OF SECTION MODULI

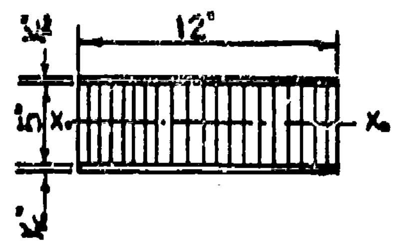
6" HONEYCOMB PANEL

$$I_o = I_1 - I_2$$
$$= \frac{12 \times 6.125^3}{12} - \frac{12 \times 6^3}{12}$$
$$= 229.78 - 216$$
$$= 13.78 \text{ in.}^4$$
$$S = \frac{I}{c} = \frac{13.78}{3.06} = 4.5 \text{ in}^3$$



5" HONEYCOMB PANEL

$$I_o = I_1 - I_2$$
$$= \frac{12 \times 5.125^3}{12} - \frac{12 \times 5^3}{12}$$
$$= 134.61 - 125$$
$$= 9.61 \text{ in.}^4$$
$$S = \frac{I}{c} = \frac{9.61}{2.56} = 3.75 \text{ in.}^3$$



4" HONEYCOMB PANEL

$$I_o = I_1 - I_2$$
$$= \frac{12 \times 4.125^3}{12} - \frac{12 \times 4^3}{12}$$
$$= 70.19 - 64$$
$$= 6.19 \text{ in.}^4$$
$$S = \frac{I}{c} = \frac{6.19}{2.06} = 3.00 \text{ in.}^3$$

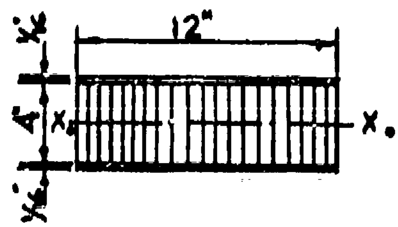
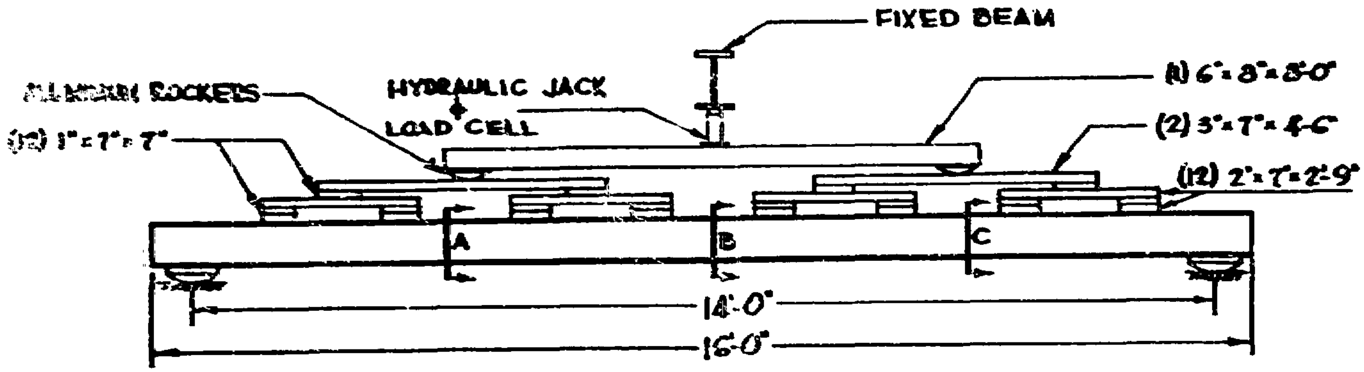
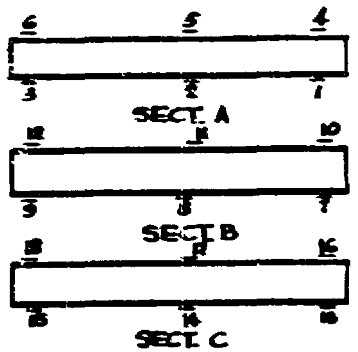


Exhibit 9

LOADING DIAGRAM - HONEYCOMB PANEL NO. 1





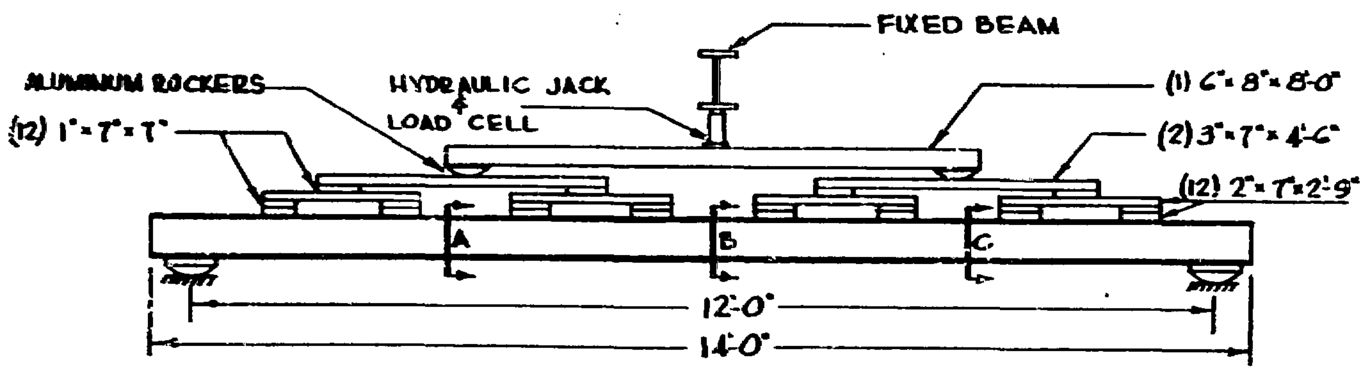
STRAIN GAGES (LOCATION)
[4" = 3'-0" AVE. X-SECT.]

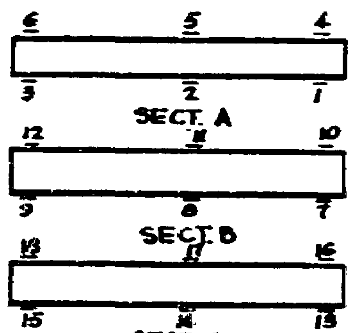
NOTES:
1. AVE. THICKNESS OF FIBERGLASS = 1/16"
2. ALL LOADING MEMBERS ARE WOOD
DL. WT. = 427#

HONEYCOMB PANEL
HONEYCOMB CORE - FIBERGLASS SKIN
WT. = 88#

Exhibit 10

LOADING DIAGRAM - HONEYCOMB PANEL NO. 2





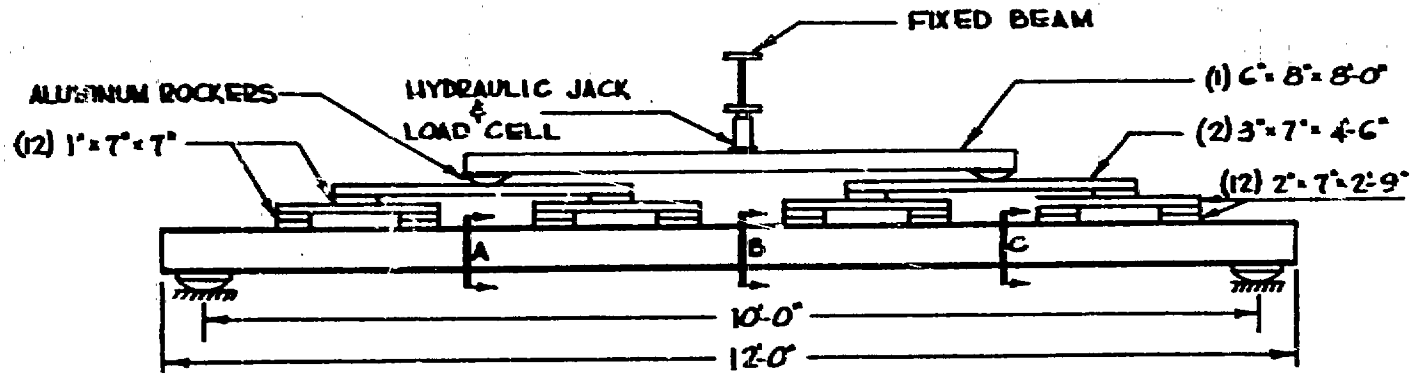
STRAIN GAGES (LOCATION)
[5" × 3'-0" AVE. X-SECT.]

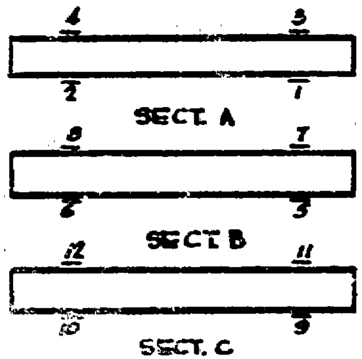
NOTES:
1. AVE. THICKNESS OF FIBERGLASS = 1/16"
2. ALL LOADING MEMBERS ARE WOOD
D.L. WT. = 427#

HONEYCOMB PANEL
HONEYCOMB CORE - FIBERGLASS SKIN
WT. = 85#

Exhibit 11

LOADING DIAGRAM - HONEYCOMB PANEL NO. 3





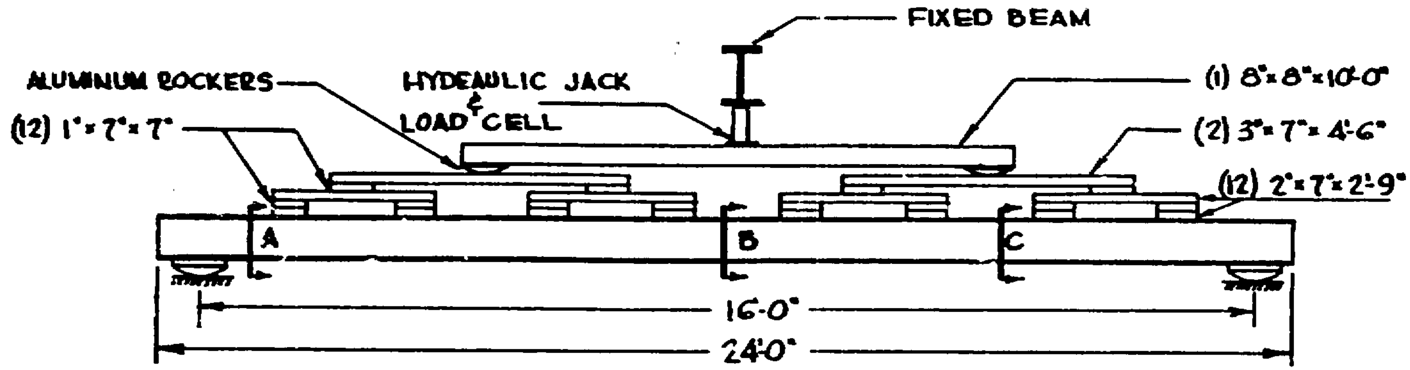
STRAIN GAGES (LOCATION)
[6" × 3'-0" AVE. X-SECT.]

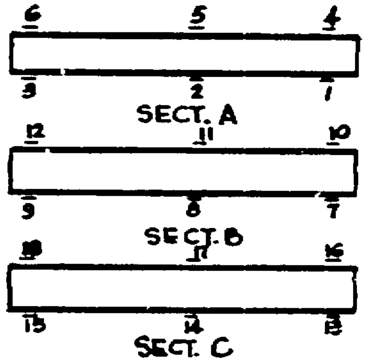
NOTES:
1. AVE. THICKNESS OF FIBERGLASS = 1/16"
2. ALL LOADING MEMBERS ARE WOOD
D.L. WT. = 427#

HONEYCOMB PANEL
HONEYCOMB CORE - FIBERGLASS SKIN
WT. = 80#

Exhibit 12

LOADING DIAGRAM - HONEYCOMB PANEL NO. 4





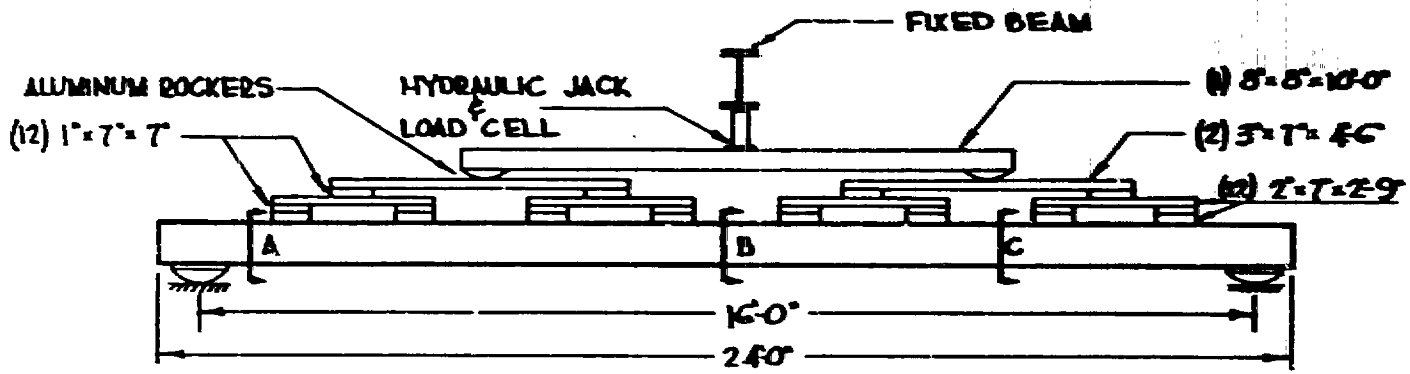
STRAIN GAGES (LOCATION)
[6"x 3'-0" AVE. X-SECT.]

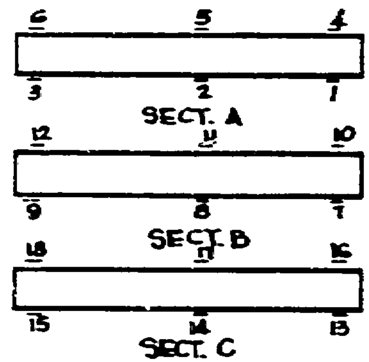
NOTES:
1. AVE. THICKNESS OF FIBERGLASS = 1/16"
2. ALL LOADING MEMBERS ARE WOOD
DL. WT. = 372#

HONEYCOMB PANEL
HONEYCOMB CORE-FIBERGLASS SKIN
WT = 126#

Exhibit 13

LOADING DIAGRAM - HONEYCOMB PANEL NO. 5





STRAIN GAGES (LOCATION)
[6" = 3'-0" AVE. X-SECT.]

NOTES:
1. AVE. THICKNESS OF FIBERGLASS = 1/16"
2. ALL LOADING MEMBERS ARE WOOD
D.L. WT. = 572#
3. INSULATION: 2 INCHES POLYSTYRENE
EXPANDABLE BEADS.

HONEYCOMB PANEL
HONEYCOMB CORE - FIBERGLASS SKIN
WT. = 161#

Exhibit 14

E= 1.11×10⁶ PSI.

HONEYCOMB PANEL NO. I
MOMENT TEST, TABLE OF STRESSES (KSI)

Moment (DL+LL) FT-K – ℄		1.780	2.660	3.080	3.520	3.960	4.400	4.840	5.280
Live Load-Kips/Girder		0.500	1.000	1.250	1.500	1.750	2.000	2.250	2.500
GAGES	1	0.450	0.844	1.071	1.254	1.488	1.680	1.910	2.185
	2	0.438	0.821	1.050	1.228	1.460	1.675	1.900	2.175
	3	0.422	0.788	1.000	1.178	1.404	1.588	1.782	2.055
	4	-0.477	-1.010	-1.215	-1.504	-1.648	-1.953	-2.175	-2.400
	5	-0.466	-0.985	-1.192	-1.470	-1.603	-1.898	-2.109	-2.340
	6	-0.450	-0.960	-1.160	-1.410	-1.530	-1.813	-2.005	-2.208
	7	0.694	1.420	1.810	2.155	2.508	2.865	3.215	3.560
	8	0.710	1.465	1.870	2.222	2.625	3.050	3.445	4.020
	9	0.744	1.499	1.910	2.263	2.660	3.120	3.530	4.100
	10	-0.682	-1.428	-1.714	-1.908	-2.255	-2.585	-2.985	-3.295
	11	-0.694	-1.492	-1.849	-2.250	-2.530	-3.000	-3.336	-3.720
	12	-0.650	-1.449	-1.798	-2.197	-2.460	-2.900	-3.233	-3.580
	13	—	—	—	—	—	—	—	—
	14	0.350	0.716	0.926	1.078	1.282	1.465	1.638	1.865
	15	0.366	0.716	0.922	1.078	1.270	1.453	1.615	1.852
	16	-0.416	-0.865	-1.082	-1.327	-1.470	-1.725	-1.910	FAILURE
	17	-0.438	-0.883	-1.110	-1.353	-1.504	-1.760	-1.953	
	18	-0.400	-0.838	-1.050	-1.277	-1.382	-1.620	-1.770	
℄ Deflection (ins.)	DL								
	LL								

PANEL THICKNESS = 4"

Exhibit 15

E= 1.11×10⁶ PSI.

HONEYCOMB PANEL NO.2
MOMENT TEST, TABLE OF STRESSES (KSI)

Moment (DL+LL) FT-K - ℄		1.520	2.270	3.020	3.770	4.520			
Live Load-Kips/Girder		0.500	1.000	1.500	2.000	2.500			
GAGES	1	0.411	0.788	1.250	1.620				
	2	0.405	0.776	1.260	1.652				
	3	0.411	0.788	1.265	1.659	FAILURE			
	4	-0.477	-0.948	-1.438	-1.875				
	5	-0.444	-0.932	-1.410	-1.852				
	6	-0.438	-0.926	-1.392	-1.802				
	7	0.666	1.260	1.970	2.580				
	8	0.622	1.170	1.902	2.400	NO			
	9	0.649	1.191	1.837	2.430				
	10	-0.786	-1.310	-2.030	-2.715				
	11	-0.654	-1.365	-2.126	-2.845	READINGS			
	12	-0.672	-1.341	-2.065	-2.740				
	13	0.438	0.854	1.304	1.709				
	14	0.422	0.777	1.310	1.620				
	15	0.466	0.888	1.350	1.780				
	16								
	17	-0.552	-0.926	-1.415	-1.848				
	18	-0.466	-0.926	-1.403	-1.820				
℄ Deflection (ins.)	DL								
	LL								

PANEL THICKNESS = 5"

Exhibit 16

E= 1.11×10⁶ PSI.

HONEYCOMB PANEL NO. 3
MOMENT TEST, TABLE OF STRESSES (KSI)

Moment (DL+LL) FT-K - ℄		1.260	1.882	2.510	3.130	3.760			
Live Load-Kips/Girder		0.500	1.000	1.500	2.000	2.500			
GAGES	1	0.333	0.633	0.922	1.220	FAILURE			
	2	0.355	0.710	0.955	1.342				
	3	-0.278	-0.677	-0.958	-1.288				
	4	-0.278	-0.666	-0.955	-1.254				
	5	0.422	0.888	1.300	1.764				
	6	0.433	0.922	1.365	1.852	NO			
	7	-0.411	-0.922	-1.355	-1.841				
	8	-0.444	-0.966	-1.420	-1.952	READINGS			
	9	0.300	0.588	0.844	1.152				
	10	0.355	0.744	1.067	1.442				
	11	-0.366	-0.766	-1.110	-1.475				
	12	-0.411	-0.855	-1.242	-1.688				
℄ Deflection (ins.)	D.L.								
	L.L.								

PANEL THICKNESS = 6"

Exhibit 17

E = 1.11 × 10^6 PSI. HONEYCOMB PANEL NO. 4 MOMENT TEST, TABLE OF STRESSES (KSI)									
Moment (DL+LL) FT-K – ℄		1.910	2.910	3.920	4.910	5.900	6.910	7.900	8.420
Live Load-Kips/Panel		0.500	1.000	1.500	2.000	2.500	3.000	3.500	3.750
GAGES	1	0.500	0.977	1.498	2.065	2.542	3.041	3.585	3.852
	2	0.466	0.921	1.476	2.020	2.475	2.953	3.463	3.707
	3	0.444	0.888	1.365	1.876	2.309	2.764	3.241	3.474
	4	-0.322	-0.644	-0.977	-1.332	-1.643	-1.965	-2.287	-2.453
	5	-0.366	-0.744	-1.121	-1.510	-1.887	-2.242	-2.620	-2.819
	6	-0.377	-0.744	-1.110	-1.498	-1.854	-2.209	-2.575	-2.775
	7	0.610	1.221	1.887	2.586	3.197	3.818	4.673	5.017
	8	0.566	1.143	1.765	2.420	2.986	3.563	4.174	4.473
	9	0.622	1.254	1.942	2.664	3.297	3.929	4.595	4.940
	10	-0.411	-0.844	-1.288	-1.754	-2.187	-2.597	-3.030	-3.263
	11	-0.433	-0.877	-1.343	-1.832	-2.287	-2.731	-3.175	-3.441
	12	-0.444	-0.910	-1.365	-1.865	-2.320	-2.764	-3.219	-3.474
	13	0.455	0.910	1.399	1.909	2.364	2.808	3.297	3.541
	14	0.466	0.910	1.399	1.920	2.364	2.808	3.286	3.530
	15	0.488	0.955	1.465	2.020	2.475	2.953	3.463	3.707
	16	-0.333	-0.655	-0.977	-1.321	-1.632	-1.931	-2.242	-2.420
	17	-0.333	-0.633	-0.988	-1.343	-1.654	-1.954	-2.276	-2.442
	18	-0.322	-0.644	-0.966	-1.310	-1.610	-1.909	-2.209	-2.386
℄ Deflection - ins.	DL+LL	0.625	1.250	1.9375	2.5625	3.1875	3.8125	4.4375	4.750
PANEL THICKNESS = 6"									

Exhibit 17 (cont'd)

HONEYCOMB PANEL NO.4
MOMENT TEST, TABLE OF STRESSES (KSI) (CONT.)

E = 1.11 × 10⁶ PSI

Moment (DL+LL) FT-K – ℄		8.920	9.430	9.930	10.400	10.900	11.400	11.900	12.400
Line Load-Kips/Panel		4.000	4.250	4.500	4.750	5.000	5.250	5.500	5.750
GAGES	1	4.074	4.329	4.606	4.828	5.095	5.350	5.594	
	2	3.918	4.162	4.429	4.629	4.884	5.150	5.372	
	3	3.674	3.885	4.107	4.296	4.540	4.773	4.984	FAILURE
	4	-2.586	-2.731	-2.953	-3.075	-3.230	-3.397	-3.541	
	5	-2.975	-3.141	-3.386	-3.541	-3.730	-3.907	-4.063	
	6	-2.919	-3.097	-3.330	-3.474	-3.663	-3.841	-4.007	
	7	5.261	5.594	5.972	6.227	6.571	8.092	—	
	8	4.718	4.995	5.295	5.528	5.828	6.149	6.405	NO
	9	5.195	5.506	5.872	6.127	6.471	6.804	7.093	
	10	-3.419	-3.619	-3.896	-4.051	-4.285	-4.484	-4.684	
	11	-3.608	-3.818	-4.118	-4.274	-4.496	-4.706	-4.928	
	12	-3.641	-3.863	-4.151	-4.318	-4.573	-4.784	-5.006	READINGS
	13	3.730	3.963	4.218	4.407	4.662	4.917	5.150	
	14	3.707	3.929	4.185	4.373	4.629	4.873	5.106	
	15	3.907	4.140	4.396	4.595	4.862	5.117	5.361	
	16	-2.531	-2.686	-2.897	-3.008	-3.186	-3.330	-3.508	
	17	-2.564	-2.720	-2.930	-3.041	-3.208	-3.341	-3.519	
	18	-2.486	-2.642	-2.842	-2.953	-3.119	-3.263	-3.430	
℄ Deflection - INS.	DL+LL	5.000	5.3125	5.6875	5.9375	6.2500	6.6875	6.9375	

PANEL THICKNESS = 6"

HONEYCOMB PANEL NO.5
MOMENT TEST, TABLE OF STRESSES (KSI)

$E = 1.11 \times 10^6$ PSI.

Moment (DL+LL) FT-K - ℄		1.960	2.960	3.960					
Live Load-Kips/Panel		0.500	1.000	1.500					
GAGES	1	0.394	0.771						
	2	0.544	0.977						
	3	0.394	0.760	FAILURE					
	4	-0.422	-0.766						
	5	-0.511	-0.955						
	6	-0.572	-1.027						
	7	0.588	1.066						
	8	0.638	1.182	NO					
	9	0.610	1.177						
	10	-0.666	-1.199						
	11	-0.638	-1.193						
	12	-0.683	-1.315	READINGS					
	13	0.416	0.783						
	14	0.472	0.882						
	15	0.450	0.816						
	16	-0.472	-0.871						
	17	-0.511	-0.944						
	18	-0.488	-0.910						
℄ Deflection - ins.	[illegible]	0.375	1.500						

PANEL THICKNESS = 6"

Exhibit 19

WIND VEL. MPH	q PSF	C	WINDWARD WALL	C	LEEWARD WALL	C	WINDWARD ¼ ROOF	C	CENTER ½ ROOF	C	LEEWARD ¼ ROOF
40	4.1	0.70	2.9	-0.50	-2.0	-0.51	-2.1	-0.95	-3.9	-0.58	-2.4
50	6.4		4.5		-3.2		-3.3		-6.1		-3.7
60	9.2		6.4		-4.6		-4.7		-8.7		-5.3
70	12.5		8.8		-6.3		-6.4		-11.9		-7.3
80	16.4		11.5		-8.2		-8.4		-15.6		-9.5
90	20.7		14.5		-10.4		-10.6		-19.7		-12.0
100	25.6		17.9		-12.8		-13.0		-24.5		-14.9

Caption: DESIGN WIND PRESSURES

NEGATIVE VALUES INDICATE EXTERNAL SUCTION ON BUILDING SURFACE.

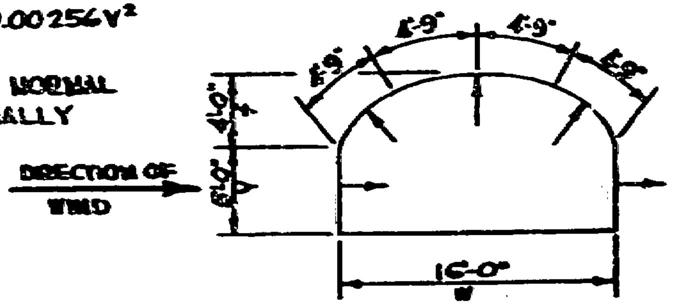
V=WIND VELOCITY IN MILES PER HOUR

q=VELOCITY PRESSURE $= 0.00256V^2$

C= SHAPE COEFFICIENT

p=DESIGN WIND PRESSURE NORMAL TO SURFACE (ACTING RADIALLY ON ROOF)

p=cq IN LBS. PER SQ.FT.



$\frac{f}{W} = \frac{4}{16} = 0.25$

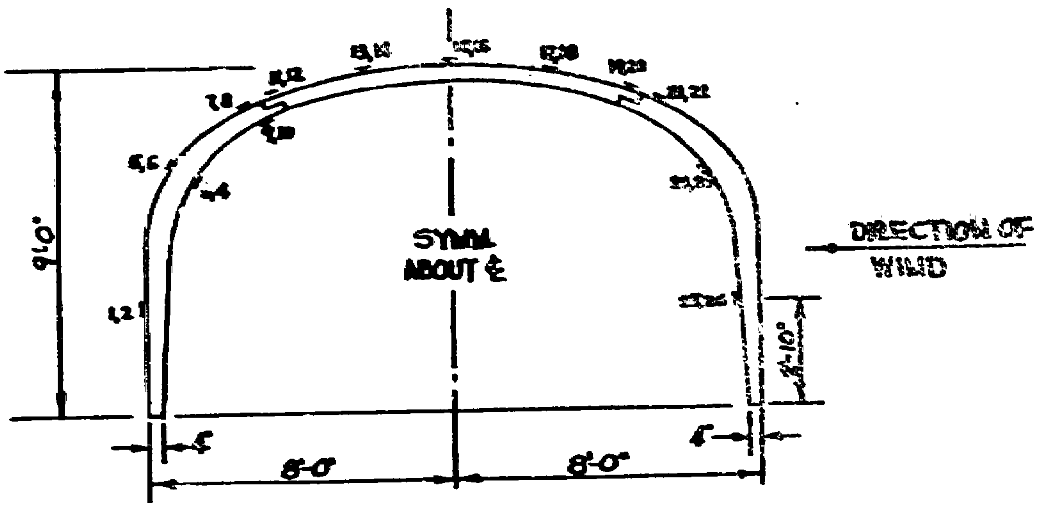
$\frac{y}{W} = \frac{8}{16} = 0.50$

WIND PRESSURE DISTRIBUTION

Exhibit 20

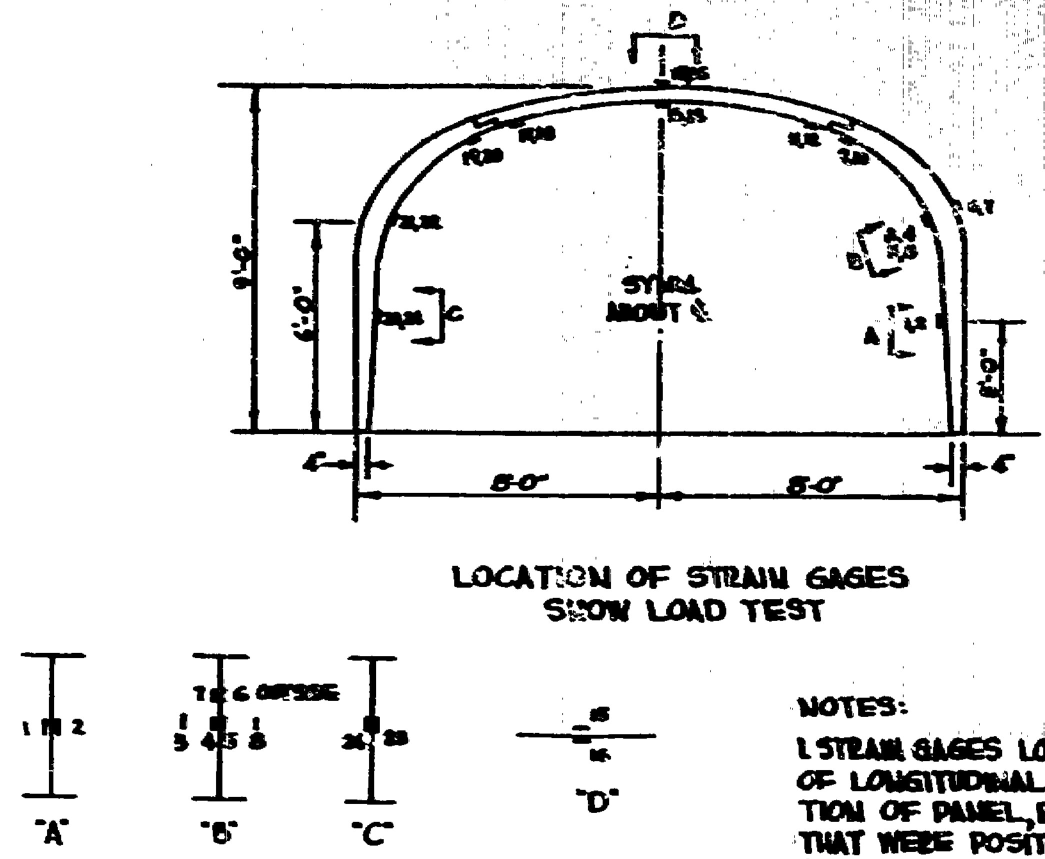
TOTAL APPLIED WIND LOAD ON 9'-0" SECTION OF BUILDING										
VELOCITY MPH	WINDWARD WALL		LEEWARD WALL		WINDWARD 1/4 ROOF		CENTER 1/2 ROOF		LEEWARD 1/4 ROOF	
	AREA-SF	P-LBS.	AREA-SF	P-LBS.	AREA-SF	P-LBS.	AREA-SF	P-LBS.	AREA-SF	P-LBS.
40	45	130.5	45	-90.0	42.75	-89.7	85.5	-333.3	42.75	-102.6
50		202.5		-144.0		-141.0		-521.4		-158.1
60		288.0		-207.0		-201.0		-743.7		-226.5
70		396.0		-283.5		-273.6		-1017.3		-312.0
80		517.5		-369.0		-359.1		-1,333.8		-406.2
90		652.5		-468.0		-453.0		-1,684.2		-515.0
100		805.5		-576.0		-555.6		-2,077.5		-636.9

Exhibit 21



LOCATION OF STRAIN GAGES
WIND LOAD TEST

NOTE:
1. STRAIN GAGES LOCATED ON BOTH SIDES OF LONGITUDINAL JOINT, ALONG RIB PORTION OF PANEL.



LOCATION OF STRAIN GAGES
SNOW LOAD TEST

NOTES:

1. STRAIN GAGES LOCATED ON BOTH SIDES OF LONGITUDINAL JOINT, ALONG RIB PORTION OF PANEL, EXCEPT FOR GAGES 3 + 8 THAT WERE POSITIONED MIDWAY ON THE PANEL FACE.
2. GAGES 6, 7, 15 + 16 WERE LOCATED ON THE OUTSIDE SURFACE OF SHELTER; THE REST, ON THE INTERIOR SURFACE OF IT.

Exhibit 23

E=0.80×10⁶ PSI.
STRESSES: KSI.

WIND LOAD STRESSES
PLASTIC BUILDING - 16'-0" × 9'-0"

Wind Velocity - MPH.		50	70	90	100
GAGES	1	0.086	-0.016	0.184	FAILURE
	2	0.084	-0.020	0.176	
	3	-0.088	-0.440	-0.616	
	4	-0.092	-0.428	-0.616	
	5	—	—	—	NO
	6	0.116	0.572	0.828	
	7	-0.108	-0.204	-0.008	READINGS
	8	-0.020	-0.108	-0.008	
	9	0.088	0.288	0.268	
	10	0.068	0.212	0.240	
	11	0.004	-0.028	0.060	
	12	-0.004	-0.036	0.052	
	13	0.080	0.344	0.664	
Deflections - ins.	VERT.	0.125	0.5625	1.125	
	HOR.	0.000	0.3125	1.3125	

E=0.80× 10^6 PSI.
STRESSES: KSI.

WIND LOAD STRESSES
PLASTIC BUILDING - 16'-0" × 9'-0" (CONT.)

Wind Velocity - MPH.		50	70	90	100
GAGES	14	0.088	0.384	0.760	FAILURE
	15	0.188	0.780	1.380	
	16	0.188	0.796	1.400	
	17	0.060	0.300	0.520	
	18	0.064	0.296	0.500	NO
	19	-0.024	-0.144	-0.264	
	20	-0.020	-0.132	-0.248	READINGS
	21	-0.044	-0.276	-0.516	
	22	-0.060	-0.324	-0.604	
	23	0.116	0.452	0.928	
	24	0.136	0.512	1.000	
	25	0.132	0.372	0.944	
	26	0.140	0.388	0.904	
Deflections - ins.	VERT.	0.125	0.5625	1.125	
	HOR.	0.000	0.3125	1.3125	

Exhibit 24

E=0.80×10^6 PSI; STRESSES: PSI; MOMENTS: FT-LBS.	SNOW LOAD TEST — PLASTIC BUILDING - 16'×12'								LOADED AREA=90SF
LOAD	450#		900#		1350#		1590#		1830#	
GAGES	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT
1	-136	35.8	-180	47.4	-260	68.5	-292	76.9	-348	91.6
2	-124	32.6	-196	51.6	-260	68.5	-308	81.1	-348	91.6
3	-148	17.4	-260	30.5	-372	43.7	-420	49.4	-484	56.9
4	-252	74.6	-500	147.9	-740	218.9	-884	261.5	-1020	301.8
5	-248	73.4	-496	146.7	-736	217.7	-888	262.7	-1000	295.8
6	276	81.6	544	160.9	824	243.8	976	288.7	1152	340.8
7	272	80.5	536	158.6	816	241.4	960	284.0	1128	333.7
8	-124	14.6	-252	29.6	-332	39.0	-412	48.4	-452	53.1
9	-188	40.7	-352	76.3	-424	91.9	-480	104.0	-600	130.0
10	-180	39.0	-328	71.1	-416	90.1	-488	105.7	-584	126.5
11	-108	23.4	-184	39.9	-168	36.4	-184	39.9	-256	55.5
12	-108	23.4	-180	39.0	-164	35.5	-164	35.5	-236	51.1
13	640	93.9	1152	169.0	1576	231.1	1760	258.1	1936	283.9
14	636	93.3	1156	169.5	1572	230.6	1788	262.2	1940	284.5
15	-428	62.8	-532	78.0	-668	98.0	-724	106.2	-772	113.2
16	-724	106.2	-724	106.2	-916	134.3	-1052	154.3	-1124	164.8
17	-104	22.5	-156	33.8	-204	44.2	-260	56.3	108	23.4
18	-104	22.5	-196	42.5	-204	44.2	-236	51.1	-28	6.7
19	-172	37.3	-336	72.8	-448	97.1	-544	117.9	-496	107.5
20	-208	45.1	-216	46.8	-312	67.6	-416	90.1	-224	48.5
21	-224	66.3	-424	125.4	-608	179.9	-744	220.1	-824	243.8
22	-268	79.3	-484	143.2	-716	211.8	-876	259.2	-972	287.6
23	-116	30.5	-196	51.6	-284	74.8	-364	95.9	-396	104.3
24	—	—	-224	59.0	-312	82.2	-392	103.2	-416	109.5
℄ Δ	0.250"		0.5625"		1.0625"		1.250"		1.375"	

E=0.80×10⁶PSI
STRESSES: PSI
MOMENTS: FT-LBS.

SNOW LOAD TEST
PLASTIC BUILDING – 16'×12' (CONT.)

LOAD	2070#		2310#		2550#		3000#		3300#	
GAGES	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT
1	-380	100.1	-348	91.6	-524	138.0	-668	175.9	-692	182.2
2	-380	100.1	-348	91.6	-532	140.1	-844	222.2	-692	182.2
3	-532	62.5	-508	59.7	-692	81.3	-908	106.7	-940	110.4
4	-1164	344.4	-1212	358.6	-1444	427.2	-1756	519.5	-1892	559.7
5	-1128	333.7	-1176	347.9	-1408	416.5	-1688	499.4	-1864	551.4
6	1296	383.4	1528	452.0	1488	440.2	1760	520.7	1944	575.1
7	1272	376.3	1496	442.6	1448	428.4	1712	506.5	1888	558.5
8	-508	59.7	-476	55.9	-652	76.6	-788	92.6	-884	103.9
9	-632	136.9	-552	119.6	-680	147.3	-640	138.7	-800	173.3
10	-624	135.2	-720	156.0	-664	143.9	-648	140.4	-784	169.9
11	-216	46.8	-272	58.9	-200	43.3	-136	29.5	-224	48.5
12	-204	44.2	-244	52.9	-180	39.0	-84	18.2	-196	42.5
13	2056	301.5	2072	303.9	2168	318.0	2416	354.3	2784	408.3
14	2052	301.0	2084	305.6	2156	316.2	2396	351.4	2724	399.5
15	-828	121.4	-948	139.0	-948	139.0	-1060	155.5	-1244	182.4
16	-1172	171.9	-1308	191.8	-1388	203.6	-1492	218.8	-1772	259.9
17	140	30.3	124	26.9	420	91.0	580	125.7	572	123.9
18	20	4.3	12	2.6	12	2.6	180	39.0	164	35.5
19	-512	110.9	-568	123.1	-592	128.3	-523	114.4	-632	136.9
20	-296	64.1	-392	84.9	-384	83.2	-424	91.9	-528	114.4
21	-888	262.7	-1080	319.5	-1192	352.6	-1304	385.8	-1488	440.2
22	-1052	311.2	-1260	372.8	-1380	408.2	-1508	446.1	-1724	510.0
23	-396	104.3	-548	144.3	-644	169.6	-668	175.9	-812	213.8
24	-400	105.3	-592	155.9	-688	181.2	-712	187.5	-856	225.4
℄ Δ	1.50"		1.625"		1.6875"		1.875"		2.25"	

Exhibit 24 (cont'd)

E=0.80×10⁶ PSI
STRESSES: PSI
MOMENTS: FT-LBS.

SNOW LOAD TEST
PLASTIC BUILDING - 16'×12' (CONT.)

LOAD	3600#		3900#		4200#		4500#			
GAGES	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT	STRESS	MOMENT		
1	-796	209.6	-804	211.7	-852	224.4	-900	237.0		
2	-804	211.7	-828	218.0	-860	226.5	-908	239.1		
3	-1076	126.4	-1116	131.1	-1172	137.7	-1252	147.1		
4	-2132	630.7	-2244	663.8	-2412	713.6	-2572	760.9		
5	-2072	613.0	-2224	657.9	-2328	688.7	-2512	743.1		
6	2096	620.1	2296	679.2	2504	740.8	2664	788.1		
7	2032	601.1	2232	660.3	2432	719.5	2592	766.8		
8	-1004	118.0	-1044	122.7	-1076	126.4	-1124	132.1		
9	-904	195.9	-960	208.0	-944	204.5	-920	199.3		
10	-888	192.4	-944	204.5	-920	199.3	-896	194.1		
11	-272	58.9	-304	65.9	-192	41.6	-144	31.2		
12	-228	49.4	-268	58.1	-148	32.1	-100	21.7		
13	2952	433.0	3264	478.7	3536	518.6	3880	569.1		
14	3076	451.1	3316	486.3	3532	518.0	3772	553.2		
15	-1364	200.0	-1380	202.4	-1444	211.8	-1532	224.7		
16	-1972	289.2	-2044	299.8	-1756	257.5	-2324	340.9		
17	428	92.7	108	23.4	108	23.4	124	26.9		
18	36	7.8	156	33.8	140	30.3	116	25.1		
19	-784	169.9	-752	162.9	-816	176.8	-904	195.9		
20	-712	154.3	-880	190.7	-952	206.3	-1000	216.7		
21	-1648	487.5	-1704	504.1	-1824	539.6	-1920	568.0		
22	-1900	562.1	-1988	588.1	-2116	626.0	-2236	661.5		
23	-852	224.4	-860	226.5	-908	239.1	-932	245.4		
24	-904	238.0	-904	238.0	-960	252.8	-976	257.0		
℄ Δ	2.3125"		2.5625"		2.7500"		2.875"			

Exhibit 23

SNOW LOAD TEST LONG RANGE LOADING			
LOAD PSF	DATE	DEFLECTIONS - INS.	
		FRONT	BACK
0	3/9/62	0	0
20	3/9/62	1.125	1.250
20	3/12/62	1.250	1.1875
0	3/12/62	0.125	0.250
30	3/12/62	1.500	1.3125
30	3/13/62	1.750	1.5625
0	3/13/62	0.375	0.3125
40	3/13/62	2.125	2.000
40	3/14/62	2.375	2.375
0	3/14/62	0.625	0.4375
50	3/14/62	3.250	3.000
50	3/14/62	FAILURE	

APPENDIX C

The Materials Branch
U. S. Army Engineer Research and Development Laboratories
Corps of Engineers
Fort Belvoir, Virginia

ERD SM

17 July 1961

EVALUATION OF GLASS REINFORCED PLASTIC SKIN ON EXPERIMENTAL PLASTIC BEAMS

Report No: 9289-1

Requested by: Special Equipment Branch

Authority: 8F71-04-001-04

1. The purpose of this investigation was to determine the physical properties of the glass fiber reinforced plastic skins on some experimental plastic beams. The density of the foam core was to be determined where this showed a variation in structure. The beams were designated by the code 1a - 1d and 2a - 2d.

2. The beams were made in the Model Shop by spraying the inside of a mold with a polyester resin and glass fiber mixture and then pouring into the interior a polyurethane foam mixture. The excess foam was cut off and the open side then sprayed with the resin glass fiber mixture.

3. The properties of the skin laminate were determined in accordance with the following methods of Federal Specification L-P-406b, "Plastics, Organic: General Specifications, Test Methods":

Method No.	Title of Method
1011	Tensile properties of plastics.
1021	Compressive properties of plastics.
1031	Flexural properties of plastics.
1041	Shear properties of plastics.
5011	Specific gravity by displacement of water.
7061	Resin in inorganic-filled plastics.

The specific gravity of the foam was determined in accordance with Method No. 5012, specific gravity from weight and volume methods.

4. The results of the tests are shown in Table III. They indicate that the glass content was extremely low; hence, low physical properties could be expected. This was found to be the case. Glass content ranged from 21.90 - 27.86 percent, tensile strength from 7,010 - 9,690 psi, compressive strength from 10,000 - 15,900 psi, flexural strength from 12,300 - 19,900 psi, and shear strength from 6,150 - 8,570 psi. The wide variation was probably due to large variations in thicknesses of the laminates and to uneven distribution of the glass fibers. It has been found possible to obtain laminates by the process used with as high as 50 percent glass. It would appear that the ratio of the resin to glass must be changed to accomplish this. Variation of the foam core was from 1.4 to 28 percent. In three of the panels, there was no difference at all. In a previous investigation, it was shown that the dispensing machine was at fault in that the components were improperly mixed.

5. It is concluded that the laminate comprising the skin has a low glass content and, hence, has low physical properties usually associated with low glass content. The foams in the panels varied in density from 1.4 to as high as 28 percent.

6. It is recommended that an attempt be made to upgrade the strength by using a higher ratio of glass to resin than was used in making the panels. Modifications to the existing machine for dispensing the foam should be made to obtain better uniformity, or else a better machine should be procured.

Submitted by: S. GOLDFEIN
Chief, Plastics Section

Forwarded by: A. W. VAN HEUCKEROTH
Chief, Materials Branch

Table III. Properties of Glass Reinforced Plastic Skin and Foam Core

Property	Beam							
	1a	1b	1c	1d	2a	2b	2c	2d
Specific Gravity	1.41	1.44	1.44	1.46	1.49	1.44	1.52	1.48
Glass Content (%)	23.73	22.58	21.95	21.90	26.87	25.81	27.86	22.79
Tensile Strength (psi)	7,400	7,770	7,010	7,710	8,780	9,270	9,690	9,090
Tensile Mod. (psi x 10^6)	0.91	0.98	1.00	0.94	1.01	1.05	1.06	1.06
Compressive Strength (psi)	12,400	1[illegible],700	13,700	12,900	10,000	15,800	15,900	12,500
Flexural Strength (psi)	12,300	15,100	13,100	15,400	17,900	19,900	17,900	12,960
Flexural Mod. (psi x 10^6)	0.76	0.96	0.56	0.74	0.95	0.85	0.80	0.79
Shear Strength (psi)	7,000	7,650	6,150	6,700	6,180	7,380	8,570	7,520
Density of Foam (lb/ft^3)	2.01 2.31	2.11 2.41	2.09 2.18	2.18 2.21	2.17	2.14	1.97 2.53	2.06

APPENDIX D

The Materials Branch
U. S. Army Engineer Research and Development Laboratories
Corps of Engineers
Fort Belvoir, Virginia

ERD SM

22 A[illegible] 19[illegible]

TEST PLASTIC PANEL ON HONEYCOMB

Report No: 9506-1

Requested by: Special Equipment Branch

Authority: Project No. 8F71-04-001-04

1. The purpose of this work was to determine the [illegible] compressive strength, flexural modulus of elasticity, and [illegible] content of a glass reinforced plastic sheet skin. The sheet was fabri[illegible] from glass fiber Rovecloth and a laminating resin. It was the skin of a sandwich construction composed of a cardboard honeycomb supplied by the Special Equipment Branch.

2. For the flexure, tensile, and glass content tests, three specimens each were cut from the top and bottom of the plastic panel. Due to the variation in thickness of the panel, each specimen was sanded to approximately a uniform thickness. The properties were determined according to methods listed in Federal Specification L-P-406b, "Plastics, Organic: General Specifications, Test Methods," dated 27 September 1951. Due to the small thickness, it was impossible to determine the compressive strength by ordinary means. It was estimated by the calculation of the penetration index.

Property	Test Method
Tensile Strength	Method 1011, with specimens cut from the specification of figure 1011A.
Flexural Modulus	Method 1031, with specimens cut from the specification of figure 1031.

Glass Content	Method 7061, with specimens cut from the pieces used for the flexure tests.
Compressive Strength	The specimen was a piece of the original laminate.
Penetration Index	Method as described in USAERDL Technical Report 1633-TR, "Development of Nondestructive Test for Plastics."

3. The results of the tests are listed in Table IV.

4. The differences in values from the arbitrary top and bottom of the honeycomb are probably due to the variation in thickness of the laminate, operational procedures, and the actual physical structure of the Rovecloth and resin. The original laminate was approximately 1/16 inch in thickness, and after sanding to a uniform thickness, it was about 1/32 inch thick. It was noted that the portion of the laminate sanded was pure resin. To check the validity of the compression results as estimated from the penetration index, the tensile strengths were calculated by use of the penetration index. These values compared favorably with the actual experimental values, so it can be assumed that the compression results are fairly accurate. The glass content reported was that of the test specimens because of the irregularity of the original laminate.

Upon consulting a fiberglass manual, it was found that tensile strengths of this type of laminate with the reported glass content were approximately 24,000 psi and compressive strengths were 22,000 psi.

5. It is concluded that:

a. The laminate is of low quality and strength and is highly variable in physical properties.

b. The sanding operation makes the panel appear to be better structurally than it actually is.

Submitted by: FRANK J. SAURO
Plastics Section

Forwarded by: A. W. VAN HEUCKEROTH
Chief, Materials Branch

Table IV. Test Results for the Panel on Honeycomb

Test Performed	Panel Location of Laminate	Average Value	Deviation
Compression (psi)	Top	10,100	$\pm$ 2,530
Compression (psi)	Bottom	11,200	$\pm$ 2,700
Flexural Modulus (psi)	Top	1.29×10^6	$\pm 0.14\times10^6$
Flexural Modulus (psi)	Bottom	0.94×10^6	$\pm 0.11\times10^6$
Tensile (psi)	Top	4,030	$\pm$ 620
Tensile (psi)	Bottom	7,980	$\pm$ 3,360
Glass Content (percent)	Top	54.9	$\pm$ 0.9
Glass Content (percent)	Bottom	45.0	$\pm$ 1.8
Penetration Index	Top	1.36×10^6	$\pm 0.35\times10^6$
Penetration Index	Bottom	1.50×10^6	$\pm 0.37\times10^6$

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